THE POTENTIAL OF THE PUPILLARY RESPONSE IN BUSINESS RESEARCH: AN INVESTIGATION OF METHODOLOGY AND AUTONOMIC CONTAMINATION

By

ROBERT ROY BELL

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This dissertation is dedicated to my parents,
Mr. and Mrs. Alvah Roy Bell

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By

Robert Roy Bell

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The purposes of this dissertation were to replicate findings previously reported in the field of pupillometrics, develop a linear model explaining the parameters contributing to changes in pupil size, examine the feasibility of utilizing computer sampling techniques in the collection of pupillometric data, and to catalog physiological responses as covariates of the pupil. A problem limiting advanced applications of pupillometric techniques has been a condition known as autonomic contamination, a phrase describing the dilation of the pupil when exposed to anxiety-arousing stimuli. A goal of the dissertation was the utilization of several physiological indicators to define differences between pupil responses under autonomic contamination and certain other conditions.

The study involved presentation of a set of visual stimuli (slides) to a group of 29 subjects, and incorporated a randomized block design. Stimuli were divided into four types: pleasant, unpleasant, neutral, and anxiety-arousing. Light intensities were equated for the 16 slides used in the study. Two startle stimuli were used as part of the anxiety-arousing

set. Environmental factors such as room light intensity and sound levels were controlled.

A television pupillometer was used to monitor changes in pupil size. Other physiological variables measured were heart rate, systolic blood pressure, and skin potential. A dynograph direct-wiring chart recorder recorded continuous samples on each of the physiological variables. These data were converted from analog (continuous) form to digital (discrete) form by a Bunker-Raymo BR-330 process control computer, which took samples of the data at one-second intervals throughout the study. The computer controlled the timing and presentation of slides during the experiment.

A linear model of the factors contributing to pupil size changes was developed for analytical purposes. Step-wise linear regressions, the chi-square test, and analyses of variance were used to test the data. Other data analyses involved time-lags and descriptions of response magnitudes of the physiological variables under differing types of stimuli.

Results raised questions about the usefulness of current pupillometric techniques in business research. Variables in the regression models produced multiple correlations of 0.62 and 0.57, respectively, for 9-second and 3-second percent changes in pupil size. The corresponding explained variances of less than 40 percent indicate that there is a great deal of reactivity in the pupil which was not explained by the variables considered. Furthermore, the direction of pupil response to the four types of stimuli did not follow the patterns which have been previously reported by proponents of pupillometric techniques.

It does appear that other physiological variables exhibit some amount of consistency in their reactions to anxiety-arousing stimuli.

This raises the hope that one of these responses could be used as a covariate with pupil change to indicate situations in which autonomic contamination exists.

Although the results tend to question the use of current pupillometric techniques in business applications, there are certain areas of laboratory research where they may still be useful. A cost/benefit study of the feasibility of using a mini-computer in the gathering of physiological data in the laboratory was performed. Results indicate that the use of computers as a laboratory tool can be justified in many circumstances.

CHAPTER 1

INTRODUCTION

In any organization, the processes necessary for ongoing activity and success of the enterprise are carried out by human beings. The study and practice of management, therefore, has implicit in it a need for understanding people--how they work, how they think, and how they can be most effectively utilized for progress toward organization goals. As Likert has said, "of all the tasks of management, managing the human component is the central and most important task, because all else depends upon how well it is done" (1971, p. 197).

Information on many different aspects of the human variable has been compiled. One of the most elusive, most hard-to-get-at areas of human behavior lies in the area of attitudinal and emotional feelings held by people. Yet these are unquestionably among the most significant determinants of human behavior. The research described in this paper was an attempt to further refine a new and promising technique for assessing these types of variables.

Data Assessment Problems

The internal states of individuals are probably among the most difficult of phenomena to measure. Many attempts have been made to develop unbiased yardsticks of the emotional and attitudinal responses of people. Conventional measures of these responses (such as paper-and-pencil question-

naire-type surveys) have been criticized on the basis of their inability to differentiate "true" reactions from those containing elements of artifact. In many situations, conventional measures are still relatively accurate and useful. In some situations, however, particularly in industry and in market research, respondents may have some reason to conceal their true attitudes and, in these situations, the traditional approach to measurement may be limited in its usefulness.

Lapiere (1934) was one of the first to report a discrepancy between how individuals, in response to a questionnaire, said they would act, and how they actually behaved. Cook and Selltiz (1964) presented a more comprehensive analysis of the problem of obtaining honest and valid questionnaire reactions from respondents. They noted:

> Susceptibility of overt response to distortion--that is, the possibility of discrepancy between private and overt response--would seem to be a function of three characteristics of the [measurement] instrument: the extent to which its purpose is apparent, the extent to which the implications of specific responses are clear, and the extent to which responses are subject to conscious control (p. 222).

The problems of social desirability (responding with the socially "correct" answer: Rosenthal, 1966), demand characteristics (cues which convey the goals of the study: Orne, 1969), and evaluation apprehension (fear of being negatively evaluated: Rosenberg, 1969), have also been suggested as contributors to bias in most types of questionnaire measures. Krugman (1964), in a marketing research study, surveyed results which show how social desirability and demand characteristics interact to distort several types of questionnaire data.

Other types of methodologies used in attempts to assess emotional and attitudinal responses, such as the projective techniques used by McClelland, have proved to be somewhat useful. Their validity coefficients are usually low, however, perhaps due to the fact that scoring of a subject's responses is so difficult. The training required to be able to use projective assessment techniques is long and rigorous, and the scoring methodology at best presents many areas where errors of interpretation or other experimenter effects could bias data. The score on some types of projective techniques, in addition, is to a large degree a function of the vocabulary of the respondent (see McClelland, 1969). Both questionnaire methods and projective techniques, therefore, are subject to several sources of assessment error.

The Potential of Pupillometrics

The development of pupillometric measures of attitudinal/emotional response (Hess and Polt, 1960; Hess 1965) presents the hope of circumventing some of the errors associated with paper-and-pencil questionnaire types of measures and projective techniques. The theory of pupillometrics is based on the hypothesis that the pupils dilate in response to pleasurable or favorable stimuli, and contract in response to negative or distasteful ones. Since the eye is part of the autonomic nervous system, individuals presumably cannot consciously control changes in the pupil.[1] If it is

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[1] The research on conditioning of the pupillary response has produced equivocal results. Several investigations (Cason, 1922; Metzner and Baber, 1939; Girden, 1942; Crasilneck and McCranie, 1956) reported positive results in attempts to condition the pupil. It seems that just as many studies, however, reported contrary findings (Stickle and Crenshae, 1934; Wedell, et al., 1940; Hilgard, et al., 1949; Young, 1954). Even when conditioning is achieved, however, the process is quite long, and appears to be limited to a specific type of individual.

possible to measure changes in the pupil, and if the logic mentioned above is valid, then it should be possible to obtain a true or objective measure of attitudinal responses to a stimulus.

Pupillometric assessment should offer several advantages over other types of reaction indicators. The response to the stimulus is very fast --usually beginning in less than a second. As mentioned previously, it is difficult to fake a pupillometric response, since pupil changes are autonomic (i.e., not subject to conscious control). A third possible advantage may stem from the bi-directional changes of the pupil--while most physiological indicators give only an indication of the size of the response, pupil changes show both size and direction. Previous work with physiological variables, such as that done by Cooper and Pollack (1959) on prejudicial attitudes and the galvanic skin response (GSR) might have derived more benefit from the bi-directional pupillary response approach.

Traditional Pupillometric Techniques

The methodology employed in pupillometric experiments has been outlined by Hess and Polt (1960) and Hess (1965). Briefly, a pupillometric experiment requires some type of stimulus input device, and some type of device for recording pupillary change. Most pupillometric experiments have involved visual stimulus presentation, and have therefore utilized slide projectors as stimulus input devices. Other types of stimuli which have been used include liquids (for taste research), still- and motion-pictures (for market research), sounds (auditory research), and several types using

cognitive information processing, physical work, or startling sounds as independent variables. Most experimenters use rapid frame cameras to take pictures of the eye, and measure changes in pupil size from the pictures.

In the most common type of pupillometric study, the subject is seated before a rectangular box with a view screen in one end. In order to minimize measurement errors resulting from head movement, the subject's head is usually immobilized (placed in a chin rest, sometimes with an elastic strap holding the forehead against a bar). Equipment for projecting slides into the view screen is situated outside the box. A mirror system whereby a motion picture or rapid frame camera can photograph changes in the eye is used. The mirror is placed below the subject's line of sight, at a 45° angle, so that a camera mounted in the side of the box can photograph the eye. Since the eye is highly reactive to light changes, slides are usually controlled for light intensity, and photography is performed using infra-red equipment. When developed, the photographs are measured by hand, using calipers or millimeter scales or grids.

Pupillometrics in Business Research

As will be seen in Chapter II, pupillometrics was first employed as a business research method in the field of marketing research in the 1960's. The potential of pupillometrics in this and other business fields will be discussed below.

The Personnel Function

The personnel function is an area of managerial decision making which may benefit from more accurate information about attitudes and values held

by potential and present employees. This statement must be qualified by the possibility that specific jobs may not require that prospective employees' attitudes/values be evaluated, simply because measures of these variables have been shown to have little predictive validity--i.e., have little or no relation to success on the job (Porter and Lawler, 1969). A question that has not been answered, however, is whether the low validity coefficients are caused by no relationship between the causal and dependent variables, or because poor measurement techniques have produced inaccurate reading of the variables.

There are some types of managerial positions where specific attitudes and values have been shown to be critical components of success (Levinson, 1964). Certain positions, for example, require that incumbents be able to perform effectively in situations involving substantial uncertainty and high risk. Many individuals have to assume responsibility for handling and committing large sums of corporate funds. Other attitudes and values which may be important include those concerning minority groups, corporate ethics, social responsibility, or those necessary for working in "organic" forms of organizations.

Although pupillometrics is not today at a stage where attitudes and values such as those mentioned above could be readily measured, it is this type of difficult measurement which is contemplated for advanced applications of the technique. It may be that physiological measures, when coupled with other types of assessment, will provide practitioners with the type of data needed to evaluate candidates along these dimensions of "personality".

Certain ethical questions and questions of acceptability are raised when industrial applications of physiological measurement systems are contemplated. In organizations where high level job candidates are normally conducted through some type of psychiatric or psychological evaluation procedure, pupillometrics may be accepted as a matter of course. In organizations where the technique may be deemed undesirable, pupillometrics may still contribute meaningfully. One of the hopes of developing an easily useable and accurate method for evaluating attitudes and values is to use it as a tool for validating other types of devices which may be useful or more acceptable for some types of assessment problems.

Another application related to the personnel function lies in the area of human factors engineering/work design. Pupillometrics has been shown to be a useful indicator of certain types of stress and anxiety levels (Hess, 1968b), and of noise levels (Nunnally, et al., 1967). Pupil response systems might prove to be valuable aids in designing jobs and work environments through the study of their effects on physiological systems.

Marketing Research

Perhaps pupillometrics is one of the oldest known marketing tools. Hess (1965) noted that Chinese jade dealers had employed the technique for centuries, watching their client's eyes to tell when his interest in the product was highest, then making the sales pitch. More scientific studies of the pupil in marketing research were conducted by Brandt (1945), who used "ocular photography" to measure responses to advertising messages.

More recently, pupil dilation and eye motion (or pupil track) have been suggested to be useful in measuring package design effectiveness (West, 1962), television commercial interest peaks (Krugman, 1964a), and product response (Business Week, 1967). Krugman (1964b) reviewed a series of studies where pupil response was shown to be indicative of interest in products such as sterling silverware and greeting cards, and also presented data supporting inter-subject consistency in pupil response rankings and sales rank data.

Hess and Polt (1966) performed research on taste stimuli which could be construed as product preference research, and were able to demonstrate correlations between pupil size and expressed preferences for certain drinks. The same study also found that both strong positive and strong negative aversive taste stimuli dilated the pupil. This finding lends credence to the hypothesis presented by some researchers that magnitude of response, not direction, may be the most important indicator of feelings. Halpern (1967) presented data on pupil responses to TV commercial and packaging, and noted that contractions were usually found to be associated with stimuli which "lack the power to interest or arouse the viewer" (p. 7). Hess (1968a) reviewed additional successful applications of pupillometrics to advertising and packaging research.

Scope of the Problem Area

Methodological Improvements

Methodology is a factor limiting the overall usefulness of most new techniques. In pupillometrics, areas needing improvement are methods of data collection and analysis. Typically, photographs of the eye are taken

continuously throughout a pupillometric experiment. These photographs must be developed, and are then measured by hand to determine pupil diameter on each photograph. This writer has previously demonstrated, on the basis of a simple study, that a possibility of making major errors in data interpretation exists when experimenters measure pupil diameter by hand (Bell, 1971). This problem of expectancy error is compounded by the sheer number of measurements to be made. For example, a study involving 20 subjects, with 15 stimuli (and 15 control stimuli) shown for 10 seconds each, with photographs taken at 1-second intervals during the experiment, would require the development and measurement of 6,000 photographs. Further, a lag time exists between the time the experiment is conducted and the time the experimenter determines whether his data are useable--i.e., whether the camera and film were operating properly.

One of the major goals of the research reported in this dissertation was the development of computer sampling techniques to circumvent the tedious and perhaps unreliable methods of data collection mentioned above. The method used in this research involved a TV Pupillometer (a video camera, capable of continuously recording a picture of the eye and measuring pupil diameter) tied into a Dynograph recorder (a device providing charts of pupil and other physiological changes) and a Bunker-Ramo BR-330 process control hybrid computer. The computer sampled data once per second, and converted the data from analog (continuous) form to digital (discrete) form through the use of an analog-to-digital converter. The feasibility and general applicability of this technique for laboratory and non-laboratory settings is discussed in the paper.

Autonomic Contamination of the Pupil Response

A major problem associated with pupillometrics at the present state of the art is caused by reactions of the autonomic nervous system to certain types of stimuli. Instead of being a "clean" indicator of a favorable response to stimuli, pupillary dilation is also caused by some very non-pleasurable stimuli, such as fear and pain (Hess, 1968a) and strongly distasteful liquids (Hess and Polt, 1966). Since pupil size changes associated with most stimuli are relatively small, it is highly possible that autonomic reactions could give investigators completely reversed data from what they expect. A high degree of fear associated with an attitude object, for example, could, by causing pupil dilation, indicate a very favorable respone to the stimulus. To achieve a better understanding of why these responses occur, and how they might be "controlled" (partialled out of the data analysis), a discussion of the autonomic nervous system is necessary.

The autonomic nervous system

The word autonomic has been defined as "acting independently of volition." This definition describes the workings of the autonomic nervous system (ANS)--"activities are largely involuntary, and we are usually unaware of them" (Sternbach, 1966, p. 14). The ANS is generally concerned with the regulation of the visceral system of the body, and attempts to maintain "homeostatic equillibrium" in the face of varying external factors

affecting the body (Gellhorn, 1943, p. 195). The ANS can be broken down into two antagonistic sub-systems, the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The SNS generally provides emergency responses, while the PNS attempts to mediate or slow down autonomic activities, and restore normal metabolism (Sternbach, p. 23).

Autonomic innervation of the pupil

The eye and the pupil are "doubly bound", being innervated by both the PNS and the SNS. The dilator muscles in the pupil are innervated by the SNS, while the sphincter muscles, which constrict the pupil, are controlled by the PNS (Milner, 1970, p. 177). The size of the pupil is controlled by the antagonistic interactions of the two sub-systems. In general, excitation of the sympathetic system causes contraction of the dilator muscle, which in turn dilates the pupil, while parasympathetic excitation causes the sphincter muscle to constrict the pupil (Grossman, 1967, p. 170). Several investigators believe there is an interaction

between the PNS and the SNS which causes dilation. Adler (1959, p. 176), for example, believes that inhibition of the sphincter and contraction of the dilator muscle act together to cause pupil dilation in man, while the sphincter alone contracts the pupil.

It appears that dilations of the eye resulting from fear, however, occur not from a joint working of the SNS and PNS, but from a physiological dominance of the SNS over the PNS. That is, in times of high states of fear or pain, the sympathetic system "takes over" control of the eye (Isaacson, et al., 1971, p. 235; Adler, p. 190). This finding will be the basis of the experimental design to be described later in this paper. It should be possible, if the finding is valid, to monitor the SNS and PNS and observe variables other than the pupil (heartrate, blood pressure, skin potential, for example) to define levels of SNS and PNS activation, and thereby obtain insights into the pupillary response. When both systems are normally active, the findings hypothesized by Hess should occur. When the SNS dominates, however, we should expect findings contrary to those associated with "normal" affective reactions of the pupil. If levels of activity of other autonomic variables such as the ones mentioned above can be shown to correspond with the sympathetic dominance, then the fear and pain responses can be partialled out of the pupil response by concurrently monitoring other variables.

Summary

It appears that pupillometrics is a fruitful tool for conducting research on the emotional and attitudinal feelings held by people. The technique may have applications in management and marketing research. Methodological shortcomings and autonomic contamination are two confounding variables which presently limit its usefulness. The goals of the study reported in this paper are to improve the methodology of pupillometrics and reduce the problem of autonomic contamination.

CHAPTER II

PREVIOUS APPLICATIONS OF THE PUPILLOMETRIC TECHNIQUE

One reason some researchers tend to disregard the pupil response as a valuable tool is that it has been shown to be a general indicator of many different typesof processes (Nunnally, et al., 1967). As this literature review will show, pupil change has been used as a dependent variable in attitude research, psychiatric research, marketing research, and gustatory (taste) and auditory research. Pupil size has been shown to be a general indicator of physical and mental activity, emotional arousal, and interest value of visual stimuli.

Notwithstanding the "generality" of the measure, pupillometrics still appears to be a potentially valuable tool for business research, given proper controls. This chapter will review in greater detail the investigations which have contributed to our present knowledge of pupillometrics.

Historical Developments

The contention that the pupil of the eye is a reflector of emotion has been held for some time. As early as 1765, Fontana described studies showing that pupil dilation followed the introduction of fearful or painful stimuli, even in the presence of bright light. Bender (1933) photo-

graphed subjects' pupils in the presence of simultaneous bright light and emotional stimuli, and also found a "psychic" pupil reaction.

Attitude Theory

In 1960, an investigation by Hess and Polt uncovered a relationship between pupil change and the interest value of visual stimuli. In this study, the experimenters displayed photographs of male and female pinups, a baby, a mother and a baby, and a landscape scene to male and female subjects. Pupil dilation was largest for men when viewing the female pinup, while the women showed greater pupil response to the pictures of the baby, the mother and baby, and the male pinup. This study marked the beginning of a concerted effort on the part of Hess and his associates to study the eye as an indicator of emotional reaction.

In 1965, Hess summarized the results of most prior studies of attitude and pupil size. Some of these investigations, using aversive stimuli such as pictures of sharks, cross-eyed and crippled children, or strongly unfavorable political statements, caused pupil constriction of over 3 percent change in average diameter. Other negative stimuli, such as sips of unpleasant tasting liquids, also caused constriction.

Hess also suggested, on the basis of preliminary data collected during the 1964 political campaigns, that the pupil response might be useful as an indicator of attitude change (page 5).

Pupil response was shown to be capable of differentiating between heterosexuals and self-admitted homosexuals in another study, (Hess, Seltzer and Shlein, 1965). In this pilot experiment, subjects were shown

slides picturing males and females in varying states of undress. Four out of five homosexuals had larger pupil responses to pictures of males (some up to 35% larger) while five out of five heterosexuals had larger pupil responses to pictures of females. A problem exists in this study, however, in that the larger pupil response to male pictures on the part of admitted homosexuals may be the result of a type of expectancy effect. Once subjects had admitted homosexual interest prior to presentation of the stimuli, the dilations could be physiological activation caused by something other than higher sexual interest in the male pictures--something similar to the well-known skin flush when one becomes aware he is being observed.

In a dissertation, Woodmansee (1965) evaluated the pupil response as a means of measuring attitudes toward Negroes, and found that affect-related responses, while significant during early presentations, diminished during repeated trials. He did find a significant difference between mean responses of anti-Negro and egalitarian subjects, thus providing support of Hess' hypotheses. The repeated trials investigation also produced disheartening results concerning the stability of the pupil response, which was measured to be around 0.30.

Hess (1968b) also described the peculiar results of the pupil's fear response, and discussed investigations showing that high galvanic skin response (GSR) levels were a concomitant of pupil dilation from shock or fearful stimuli. When GSR "dropped out", pupil dilation turned to constriction (p. 581). In another article (1968a), he suggested that fruitful future research should concern itself with investigations of

the relationship between the pupil and non-visual senses, and between the pupil response and other physiological measures.

Pupil Size and Mental Activity

Data showing that pupil size was directly related to mental activity were presented by Hess and Polt (1964). This experiment, where subjects were presented with mental mathematical problems of varying degrees of difficulty while their pupils were photographed, showed that mean pupil dilation was highly correlated with problem difficulty.

Word abstractness was also shown to be related to pupil size when subjects were asked to form mental images of abstract and concrete words (Pavio and Simpson, 1966). The Pavio and Simpson study found no relationship, however, between the pleasantness-unpleasantness of a word and pupil size (p. 55). Another study corroborated the first Pavio and Simpson findings in a study on pupil size and memory load, finding that "pupil diameter is a measure of the amount of material which is under active processing at any time" (Kahneman and Beatty, 1966, p. 1585).

Some studies reported in 1967 included one by Kahneman and Bailey replicating the "information load and pupil size" results reported in 1966; a report by Hudd and Anderson that pupil diameter may be a mechanism of perceptual recognition threshold, and a study by Peavler and McLaughlin on the relationship between novel stimuli and pupil size, all of which generally supported the results described in the above paragraphs. Polt (1970) described another experiment showing that subjects exerting greater mental effort had correspondingly greater pupil dilation.

Two dissertations written at the University of Oklahoma (Clark, 1971, and Johnson, 1971) investigated pupillary responses during short-term memory tasks. Both replicated the finding that amount of cognitive processing and pupillary diameter are highly related.

Psychiatric Research

A study in the field of psychiatry (Rubin, et al., 1963) suggested that pupil response may be a useful psychiatric diagnostic tool. Results showed that characteristic pupil changes in children with cystic fibrosis were significantly different than those of normal children. The study also discussed the effect of age on pupillary reactivity, noting that response characteristics tend to change as people become older.

Research reported by Sheflin (1969) investigated pupil reactions of hospitalized schizophrenics and found that, if pupil dilation is interpreted as a measure of interest, male paranoids are not more sexually interested in men than in women--a finding contrary to that held by most psychiatric researchers.

Boersma, et al., found that pupillary response was useful for studying differences in cognitive information processing in educatable mental retardates and normal children (1970, p. 143). During the same time, Tanck and Robbins investigated the predictability of the pupil response using the Dream Incident Technique (DIT), the Edward Personal Preference Schedule (EPPS) and the Repression-Sensitization Scale. They found the DIT to be fairly predictive of pupil response, while scores on the other two scales showed no relationship to pupil changes.

In another study, Good and Levin (1970) failed in an attempt to show that "sensitizers" would exert more perceptual vigilance, operationalized as pupil dilation than would "repressers", although they did corroborate previous findings on affective arousal and pupil dilation (p. 631).

More research showing pupil changes may be useful in clinical programs was reported by Kennedy (1971). This study indicated that pupil dilation could be used as an indicator of the therapeutic impact of treatment on chronic alcoholics, and may be useful for predicting recidivism (recurrence of need for treatment).

Emotional Reactions and Pupil Size

In the 1965 study discussed earlier, Hess also reported that dilated pupils in a photograph of a young woman caused greater preference for that picture than for one where the woman's pupils were of normal size. Hicks, et al., (1967) in an attempt to replicate Hess' findings, reported that pupil size showed no relationship to expressed attraction, while facial angle did have a significant effect (p. 388). Simms, however, found that pupil size in pictures had a significant effect when sex differences were controlled. Married subjects showed greatest dilation to opposite-sex pictures with large pupils, and dilated least to like-sex photographs with large pupils (1967, p. 554). Data presented by Starr and Willis (1967) also supported the dilation-attraction hypothesis.

Other studies of the relationship between pupil size and the emotions were reported in 1966. In a dissertation, Guinan demonstrated

that emotionality (operationalized through slide presentations of emotional words) did have significant impact on pupil size, and that a significant interaction between time and emotionality occurred.

Barlow (1969 and 1970) reported a positive correlation between expressed preference for photos and pupil dilation, and found that aversive stimuli did cause constriction of the pupil. In another study, he found the pupil response to be in perfect agreement with verbal preferences in a study of political candidate preferences (Barlow, 1969b).

The Hess (1965) article also reviewed some studies of the pupil response as an index of "motivation". In this study Hess and his associates deprived some subjects of food for four or five hours. The mean pupil response of this group to pictures of food was two and a half times larger than the mean response of a control group which had eaten within an hour prior to the experiments. Whether or not the term "motivation" is appropriate in this context, it does appear that these data support the Hess and Polt (1960) contention that pupil response is an index of interest value of visual stimuli.

Hess and Polt (1966) presented data showing that the pupil may be an indicator of taste sensitivity and taste preference. Five different orange beverages, together with a control beverage (water) were given to subjects. Pupil response was positively correlated with other rankings of beverage preference. Dooley and Lehr (1967), however, criticized the methodology employed by Hess and Polt, noting that controls normally employed in gustatory research were not used, and that the results may

have therefore been biased. They also noted that order effects could have biased data. In a reply, Hess and Polt (1967) stated that they had investigated order of presentation as a source of artifact, but had found no effects in visual, olfactory, auditory, or tactile stimulation experiments.

Marketing Research

In the early 1960's, Marplan, a marketing research organization, became interested in commercial applications of the Hess pupil response measuring system. The studies they conducted, usually in conjunction with Hess, were reported by West (1962), Krugman (1964) and by Sponsor magazine (1964). Briefly, findings were that pupil response was related to sales patterns of the products tested (watches, greeting cards, silverware) and was also related to coupon returns on advertisements tested. These data tended to support the thesis that pupil responses and attitudinal/emotional responses were related, and led to the hope that further research could develop a new and useful marketing tool.

The Marplan studies also showed that the pupil response could be used with moving pictures as well as still frame photos. A continuous measurement of the pupil, called the pupil interest track, was recorded while subjects watched television commercials. By monitoring pupil dilation and constriction, investigators were able to determine where interest peaks were highest and where interest had waned. Strategic placement of the main selling point, it was hoped, could be achieved

by locating the message directly after the high point on the pupil interest track. Pupil track also allowed the makers of the commercial to evaluate their product's capacity to keep viewers watching that channel and that commercial (Sponsor, 1964).

As mentioned in Chapter 1, a further use of pupillometrics to marketing researchers lies in its ability to overcome social desireability problems associated with typical written or verbal questioning procedures. Pupil change was shown by the Marplan studies to have a mathematically higher relationship to sales than do verbal and written surveys, although the differences were not always statistically significant (Krugman, p. 17).

Halpern described the potential usefulness of pupillometric techniques in "before-and-after" marketing experiments. He noted (p. 320) that, often, when subjects are called upon to make "after" responses, their replies are biased by knowledge of their "before" responses, The interview and questionnaire techniques commonly used by marketing researchers also come under fire, as discussed in Chapter 1. Halpern conducted studies showing that pupil dilation was as "good" a response index as were questionnaires for these types of experiments, while not possessing the bias and social desirability drawbacks inherent in questionnaire and interview techniques. Pupil dilation was again shown to be an indicator of interest in package design (p. 321).

A "questioning" article by Blackwell, et al. (1970) surveyed the state of pupillometric appraisal in marketing research, and noted that the technique was being used before being well understood. They stated

that there exist both "unfounded optimism" and "ill-timed skepticism" concerning the pupillometer and its applications, and echoed the call of many investigators for more research on the technique and its usefulness.

Dissenting Votes

While these studies were proceeding, publications in the field of ophthalmology appeared which have significance for pupillometric research. In particular, the works of Lowenstein and Lowenfeld (1961 and 1962) made considerable contribution to knowledge about pupil functioning, and sparked controversy over some of their findings. Their discussion of the "pupillary reflex dilation", defined as an increase in pupil size caused by sensory or emotional stimuli, or by spontaneous emotions or thoughts, supports the affect-dilation results obtained by Hess. Ophthalmologic and physiological treatises on pupil constriction, however, almost uniformly disagree with the Hess assertion that constriction is affect-related (Lowenfeld, 1966). According to Woodmansee (1965), pupillary constriction can occur for any of three reasons:

> 1. The light reflex, whereby "an increase of light flux to the retina results in a flow of efferent impulses from the oculomotor nucleus to the sphincter muscle, thus actively constricting the pupil."
>
> 2. The near-vision reflex, which occurs when the eyes shift from focusing on a distant object to focusing on an object less far away.
>
> 3. The relaxation of the dilator muscle, caused by a decrease in arousal following close on the heels of a high-arousal, reflex dilation condition (page 7).

It is this third phenomenon which Lowenfeld and Woodmansee hypothesize as a possible cause of the constriction measured by Hess.

Another type of criticism was contributed by Nunnally, et al. (1967). They described a series of experiments in which pupil size was shown to be related to muscle tension, sound levels, affect, novelty of pictures, and fear (threat of gunshot). They noted that pupil size seems to be directly related to fear through autonomic contamination (p. 154), as discussed in Chapter 1. The authors concluded that pupil response was such a generalized reaction as to be almost without value for studying complex emotional stimuli and responses.

Summary

The record presented above tends to obscure any patterns which may have emerged from the past decade of study. A summary content analysis of these articles reviewed in this chapter is presented in Table 2-1. Perhaps the major conclusion that can be drawn at this stage is that the pupil does respond to stimuli. Whether or not it is possible to accurately assess such things as attitude and emotional reactions is not yet clear. Many studies have presented evidence of ability to measure attitudes; others, just as rigorously controlled, have found no consistent relationship between attitudes/emotions and the pupil response. Before the question can be resolved, a much more precise methodology for measuring the variables of interest must be developed, and many of the artifacts now associated with the pupil response must be cataloged and controlled. The rest of this study is an attempt to contribute to these goals.

TABLE 2-1

SUMMARY OF PUPILLOMETRIC STUDIES

Authors	Topic
Bell, 1971	10, 11
Blackwell, et al.,1970	4
Boersma, et al., 1970	2
Bradshaw, 1967	2, 3
Bradshaw, 1968	2
Dooley and Lehr, 1967	2, 7, 11
Francis and Kelley, 1969	6
Guinan, 1969	1, 2, 5
Halpern, 1967	4
Hess, 1965	1, 10
Hess, 1968a	4, 10
Hess, 1968b	6, 10, 14, 15
Hess and Polt, 1960	6
Hess and Polt, 1964	2
Hess and Polt, 1966	7
Hess and Polt, 1967	7, 11
Hess, et al., 1965	1, 3, 6
Hicks, et al., 1967	3, 5, 11
Holmes, 1967	8
Kahneman & Beatty, 1967	2
Krugman, 1964a	4, 10
Krugman, 1964b	4
Kimmel, 1967	8
Landauer & Feakes, 1967	10
Lowenfeld, 1966	10, 11
Nunnally, et al., 1967	2, 3, 6, 10, 15, 16
Pavio and Simpson, 1966	2, 3, 5
Rubin, 1961	13, 14
Rubin, et al., 1963	14
Simms, 1967	3, 6
Tanck and Robbins, 1970	5, 17
Woodmansee, 1965	1, 10
Television Magazine, 1962	4
Business Week, 1967	4

Key:

1 - Attitude Studies
2 - Mental Activity
3 - Arousal
4 - Market Research
5 - Emotion Studies
6 - Interest Value Research
7 - Taste Research
8 - Conditioning
9 - Auditory Research
10 - Measurement Techniques
11 - Methodology
12 - Age Difference Research
13 - Autonomic Balance
14 - Psychiatry Research
15 - Fear Research
16 - Physical Work Studies
17 - Personality Studies

CHAPTER III

RESEARCH GOALS AND HYPOTHESES

This chapter will define the objectives of the dissertation research, and will present the specific hypotheses which were tested. Although they were tested in the null form, the hypotheses listed here are in the form of expected results. Chapter IV will describe the methodology of the experiment, and the collection and analysis of data.

Research Goals

1. The validation and replication of earlier works showing that the pupil responds differentially to various stimuli.

2. The development of a linear model describing the parameters contributing to pupil change.

3. Examination of several autonomic responses to favorable, unfavorable, neutral, and anxiety-arousing stimuli, with the objective of eliminating autonomic contamination as a source of error in pupil response data.

4. Examination of an improved methodology for conducting pupillometric experiments, including computer control of stimulus presentation, analog to digital conversion of data, and real-time sampling and measurement of the pupillary response.

5. Collection and analysis of data for testing the following specific hypotheses.

Hypotheses

Pupillary Reaction

Pleasant stimuli will be accompanied by dilation, while neutral stimuli will cause no change in pupil size.

Negative stimuli will cause a constriction of the pupil.

Anxiety-arousing stimuli will dilate the pupil.

Highly pleasureable stimuli will produce greater pupil dilation than will less pleasant stimuli.

Autonomic Contamination

Magnitude covariance

Blood pressure changes will be similar in reaction when exposed to pleasant stimuli and when exposed to anxiety-arousing stimuli.

Heartrate changes will be similar when exposed to anxiety-arousing stimuli and pleasant stimuli.

Skin potential changes will be similar in reaction when exposed to anxiety-arousing and to pleasant stimuli.

Response duration

Pupillary dilation to fear-arousing stimuli will take longer to return to initial base level (at time of stimulus presentation) than will pupil dilation to pleasant stimuli, for a given level of stimulus intensity.

Heartrate will take longer to return to base line in response to anxiety-arousing stimuli than to pleasant stimuli, for the same stimulus level.

Skin potential will take longer to return to base line in response to anxiety-arousing stimuli than to pleasant stimuli, for the same stimulus level.

Blood pressure will take longer to return to base line in response to anxiety-arousing stimuli than to pleasant stimuli, for the same level of stimulus intensity.

CHAPTER IV

PROCEDURE

Experimental Design

The study was conducted under a randomized block design. Each subject served as a block, and received each of the 18 treatments (stimuli), with the order of presentation of treatments randomized for each block. The design will be discussed in greater detail below.

Subjects

Twenty-nine persons served as subjects in the study. All were volunteer males between the ages of 20 and 40, drawn largely from two student groups in the College of Business Administration (the M.B.A. Club and Delta Sigma Pi). They were pretested through questionnaire to determine any known prior medical problems (heart trouble, eye deficiencies, etc.) which might have affected their responses. Those reporting no medical problems were asked to serve as subjects. The accompanying figure shows the flow of the procedure the subjects went through.

At the time of the study, each subject's visual acuity was tested to determine his ability to discriminate detail on slide stimuli. Since one object of the research was to determine the feasibility of

Figure 4-1. Procedure

S enters systems lab and is introduced to E's ⇒ Equipment and procedures are explained to S ⇒ S completes questionnaire and reads Snellen chart (visual acuity) ⇒ E's attach electrodes to S and seat S in dentist chair

⇓

Blood pressure sensors are attached and camera is focused on S's eyes ⇐ Reading levels are adjusted on chart recording equipment ⇐ Computer is instructed to initiate experiment ⇐ Two minute run with affect slides to familiarize S with sequencing

⇓

Rest period for S - necessary adjustments to equipment are made ⇒ Main run with affect-related stimuli 512 seconds Computer sampling ⇒ Remove electrodes Dump computer data onto punch tape Recycle equipment ⇒ S - fills out post-test questionnaire while viewing slides second time

KEY: Operation   Data Collection   Rest Period

using pupillometric techniques in field research, the very general controls mentioned above were the only ones used to select subjects. It was assumed that close controls would be lacking in field research, using subjects selected from the general adult population, and therefore any laboratory study using more specific controls would not be generalizable to this type of population.

Environment

The studies were conducted in the Systems Engineering/Human Performance Laboratory at the University of Florida. Light levels, peripheral sound, and temperature were all controlled. The same two persons (the investigator and a laboratory technician) conducted all sessions of the experiment. Occassionally, other persons sat in on the study as observers.

Figure 4-2. The Experimental Environment

Apparatus

Equipment layout followed a modification of the design used by Hess (1965, p. 48). Each subject was fitted with electrodes for measuring heartrate and skin potential. He was shown the measuring equipment, and the basic scope of the study was described. The subject was then seated in a dentist's chair, which allowed a certain degree of freedom, while restricting body movement.

The subject looked into a rectangular viewing box, measuring 27 cm. by 32 cm. by 60 cm. The box was equipped with a rear-projection screen in the end opposite the subject. The walls, top, and bottom of the box were painted flat black to effectively eliminate all outside light. A black cloth covered the box and the subject during each run of the study. The end of the box at which the subject was seated had a 10 by 13 cm. opening which circumscribed the subject's head. A chin rest, used to minimize head movement during the experiment, was recessed in the open end of the box.

Two Kodak Ektagraphic Model 850 H Carousel slide projectors, located 25 cm. to the rear of the view screen, projected slides on to the screen. The size of the projected image was reduced to 4 by 6 cm. to reduce eye search of the stimuli. The projectors were connected to a BR-330 hybrid computer which controlled the timing and presentation of the slides.

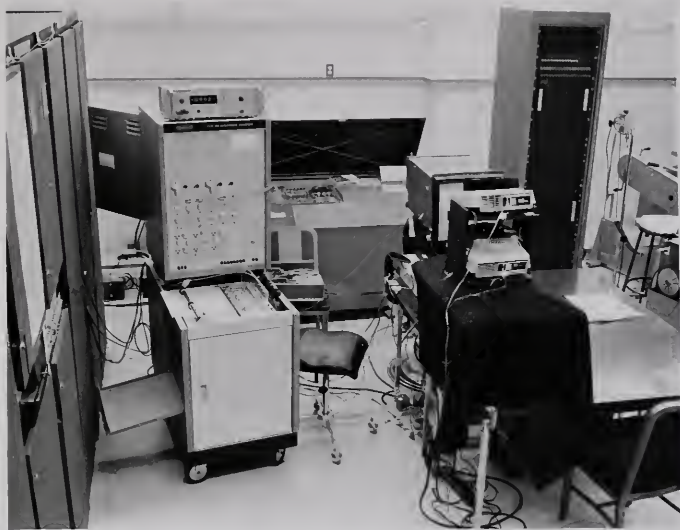

Figure 4-3. Equipment

During the experiment, the subject wore a set of dictation headphones. The headphones, connected to a Revere-Wollensak tape recorder, presented uniform white (random) noise during the study.

Just to the left of the subject's line of sight, a Whittaker Model 800 TV Pupillometer (TVP) was situated to take continuous readings of the size of the subject's left pupil. The TVP is a closed-circuit television system, incorporating a horizontal scanning technique and a signal processor which measures and displays pupil diameter. The TVP was equipped with a television monitor and remote controls which allowed the experimenter to adjust focusing so that proper settings could be found for each subject. The equipment operated in the near infra-red,

with a low intensity near infrared source illuminating the eye.[1] With the exception of one subject, the light source produced no reported discomfort in this study.

Figure 4-4. Recording Equipment

A Beckman Type RM Dynograph direct wiring recorder, capable of measuring up to six physiological variables simultaneously, was situated near the main equipment stand. Sensors on the subject were connected to the recorder, which displayed readings on a continuously moving chart and simultaneously transmitted data to the computer system described below. The recorder contained a timer unit and event market which were used to

[1]Source: Whittaker Corporation, Space Sciences Division, Instruction Manual for Series 800 TV Pupillometers.

note event changes such as the introduction of new stimuli.

Figure 4-5. The Experiment in Progress

The computer system monitored the experiment continuously and transformed the data from direct analog readout of the physiological variables to digital form, using punched paper take as an output medium. The data on paper tape were then transferred to magnetic tape and analyzed using the IBM 360/65 computer. With the exception of data transfer programming, there was no human interaction with the data until after analysis had been completed. The measurement techniques used in the system were validated using "known" responses (such as artificial pupils of known diameter) before the experiment was begun. Changes

were measured in tenths of millimeters, on a scale of 1.0-10.0, so the measurement system was sensitive to changes as small as 1 percent per second.

Stimuli

Stimuli for the studies reported in this dissertation were a set of black and white 35 mm slides. A series of 58 slides was developed for pretesting. Of these 58, 16 were chosen for use in the study. In the slide selection pretest, 14 raters judged the slides using semantic differentials developed from the manifest anxiety scale and from evaluative scales used by Osgood, et al. (1967). A copy of the rating questionnaire is included in Appendix I of this paper. The slides chosen for the study were those exhibiting high scores along a specific dimension and having low variability. The dimensions of interest were pleasant-unpleasant, fear/anxiety, and interest value. The slides chosen are described in Table 4-1.

Scoring the questionnaires

The set of semantic differentials shown in Appendix I was used to evaluate each slide. The set was made up of 3 subsets of scales, or factors.

The pleasant-unpleasant factor was composed of the following semantic differentials:

Disgusted-elated
Gloomy-cheerful
Hostile-friendly
Unpleasant-pleasant
Unfavorable-favorable
Negative-positive

Table 4-1

Affective Ratings (Independent Judges) and Luminosity Scores of Slides

Stimulus Content	Judged Affect[a] Fear μ	σ	Pleasantness μ	σ	Predicted Response Type	Luminosity: Overall Brightness[b]
1. Picture, Snarling Dog	28.0	2.7	39.6	3.2	Fear	-719
2. Picture, Deformed Baby	27.9	3.2	35.1	2.1	Unpleasant	-720
3. Picture, Ferret (animal)	17.6	1.7	20.3	2.0	Pleasant	-685
4. Picture, Deformed Baby	24.4	2.8	32.2	2.7	Unpleasant	-727
5. Picture, Emaciated Child	25.0	3.0	31.6	2.3	Unpleasant	-716
6. Picture, Deformed Baby	23.8	1.6	32.6	1.7	Unpleasant	-728
7. Line Drawing, Triangle	20.4	0.5	23.6	2.0	Neutral	-693
8. Charcoal Sketch, Girl	15.7	1.4	20.8	0.8	Pleasant	-725
9. Picture, Chair	20.1	0.5	24.5	0.9	Neutral	-690
10. Charcoal Sketch, Nude	19.3	1.7	21.1	2.3	Pleasant	-719
11. Picture, Smiling Girl	13.3	3.8	13.5	3.5	Pleasant	-709
12. Line Drawing, Block	19.5	0.5	23.7	1.5	Neutral	-719
13. Line Drawing, Rectangle	20.0	0.0	24.4	0.5	Neutral	-693
14. Picture, Child in Pain	25.7	3.5	30.5	3.7	Unpleasant	-722
15. Picture, Hanging Man	23.6	2.6	29.9	2.6	Unpleasant	-705
16. Line Drawing, Woman	20.0	0.0	24.0	0.0	Neutral	-725
Control Slides						
C2 Blank					Neutral	
C2 Blank					Neutral	
C3 Blank					Neutral	
C4 Blank					Neutral	
C5 Blank					Neutral	

[a]Range Possibilities for Response Categories: Fear: 5-35, Neutral=20.0; Pleasantness: 6-42, Neutral=24; in both categories, high scores imply Negative Reactions - i.e., High Fear and Unpleasantness, respectively.

[b]Measured with Weston Light Meter and transferred to digital form. The range -685 to -728 corresponds approximately to the range 600 to 975 footcandles, respectively.

Since each scale had a range of from 1 to 7, the possible range of scores was 6-42. If a person had checked all scales at the extreme "pleasant" side of the scale, the score value for the factor would be 6. Conversely, checking all the scales at the negative end would have produced a factor score of 42. Checking all scales at the "neutral" midpoint value would have produced a score of 24. The middle point appears to be a true "neutral" position on the pleasant-unpleasant dimension.

The anxiety-arousing factor was composed of the semantic differentials:

Unafraid-afraid
Nervous-calm
Insecure-secure
Tense-relaxed

The lowest possible anxiety factor score for a slide was 5,.and the highest anxiety factor value was 35. Unlike the pleasant-unpleasant factor, it appears that the anxiety scale does not yield a true neutral position, if by neutral we mean lack of anxiety. Rather, this scale appears to produce a step-score, with degree of anxiety increasing as the score increases.

A single semantic differential (interesting-uninteresting) was used to evaluate slides along the "interest value" dimension.

To ensure that the groupings of slides used as independent variables were indeed different from each other, the medians test was computed for each dyad of grouping, using subjects' questionnaire data. The groups in each dyad were significantly different from each other at the .01 level (for the pleasant-unpleasant dyad, X^2 = 131.49; for the pleasant-neutral dyad, X^2 = 131.49; for the pleasant-neutral dyad, X^2=34.31; for the unpleasant-neutral dyad, X^2 = 164.49; each dyad tested with 1 degree of freedom).

After the 16 stimulus slides were settled on, Kodak #96 Gelatin neutral Density Filters were added to each slide, as needed, to develop closely balanced light intensitites. All slides and control slides used in the study had the same intensity, within limits, so that any pupillary

response occuring could not be construed as a light reflex. Table 4-1 also presented the range of scrambled light intensities for the set of stimuli.

Stimulus Presentation

A blank control slide was projected on the screen while the subject was being seated in the chair and adjusted to the equipment. As soon as all sensors were reading properly, a two-minute study similar to the main study was conducted to familiarize the subject with the equipment, timing, and general environment he would be in during the study. At the end of two minutes, he was allowed to rest and was asked about his comfort. This time also allowed the experimenters to make any necessary readjustments of the equipment. The subject was then cautioned about moving his head back from the headrest. He was also asked to contain swallowing and most eyeblinking to the time when control slides were on the screen, since these types of movements introduced errors into the measurement system. He was informed that, at some time during the experiment, he might hear a buzzer, and that it was part of the experiment. He was cautioned not to move away from the equipment at the sound of the buzzer.

The subject was then asked to readjust his head into the chin rest, the camera focus was checked, a black cloth was placed over the subject and over the equipment, and the main experiment was begun. A blank slide was projected on the screen during the period described above. The blank slide remained on the screen for a period of eighteen seconds after the computer had been given the instruction to begin the experiment. Once given that instruction, the computer controlled both

slide projectors, and operated them so that no light flash occured during change-over from one slide to the next. To accomplish this, the computer was programmed to start changing the slide to be projected one half second before it instructed the other slide projector to remove the slide currently being projected. Every other slide in each projector was a black slide (one allowing no light to pass through) so that while one projector was showing a stimulus or control slide, the other was showing a black slide. This "flip-flop" process was developed to allow the reduction of the light flash mentioned above to a period of less than 1/20 second.

Each stimulus slide was presented for 10 seconds, and was followed by a blank control slide presented for 20 seconds. It was hoped that the 20-second blank slide would allow response variables to return to normal levels before the next stimulus was presented. The order of stimulus presentation was randomly varied to control for order effects. Table 4-2 presents the order of each stimulus presentation.

The slide runs took 480 seconds (32 slides, half for 10 seconds each, and half for 20 seconds). At the end of this time, the subject was given a "startle" stimulus, consisting of an alarm buzzer sounding. The buzzer was attached to the wood bottom of the arm rest used by the subject, and produced both a startling sound and a simultaneous startling vibration in the arm rest. Approximately 20 seconds later, the investigator pushed the "release" switch on the dentist chair, causing it to move very rapidly downward, producing a second startle response. Because of the rapid down-

Table 4-2

Order of Stimulus Presentation

Sub-ject	Stimulus Number																	
MS	07	01	06	09	11	14	12	16	02	03	13	15	10	05	04	08	17	18
JR	02	04	15	12	01	07	16	13	14	03	08	06	05	11	10	01	17	18
BW	04	02	08	09	11	15	07	06	16	10	13	03	05	12	14	01	17	18
GH	11	03	05	16	01	07	14	06	09	08	10	04	15	12	02	13	17	18
TH	16	09	02	05	13	10	15	03	08	12	01	04	07	06	14	11	17	18
DN	16	05	10	15	03	04	13	11	02	14	01	12	07	09	08	06	17	18
WS	08	02	05	10	04	09	16	06	03	14	12	13	01	15	07	11	17	18
BH	13	05	02	16	12	14	01	08	10	11	09	15	03	04	06	07	17	18
JP	01	13	04	03	11	02	06	10	12	14	08	05	09	16	15	07	17	18
EG	06	05	08	04	13	02	07	12	14	09	11	16	10	15	01	03	17	18
MB	16	13	02	15	11	03	12	04	05	06	01	07	08	14	10	01	17	18
FN	14	11	13	08	05	03	07	04	10	15	06	01	09	12	16	02	17	18
BB	10	07	02	13	15	16	09	01	12	08	04	14	03	06	05	11	17	18
TD	01	05	15	13	06	16	07	04	08	11	02	10	14	12	03	01	17	18
DP	15	04	07	01	09	16	03	05	13	08	12	06	10	11	14	02	17	18
VB	10	14	08	04	07	15	11	08	02	01	06	05	03	12	13	16	17	18
WA	07	06	11	04	13	10	01	03	14	08	05	02	09	16	15	12	17	18
DC	16	03	06	08	05	12	07	09	14	02	15	01	11	04	10	13	17	18
RS	01	03	04	07	14	13	10	05	15	02	08	16	06	11	12	01	17	18
BT	15	07	02	05	08	12	10	16	01	04	13	09	03	14	11	06	17	18
JW	07	13	09	12	14	05	06	02	15	11	16	08	10	03	01	04	17	18
BR	13	16	15	03	07	14	09	06	05	08	12	01	04	10	02	11	17	18
KK	13	16	15	03	07	14	09	06	05	08	12	01	04	10	02	11	17	18
CM	01	05	11	04	09	10	15	08	03	02	16	06	12	13	14	07	17	18
WK	09	10	16	08	04	02	12	15	06	05	03	01	07	04	11	13	17	18
BL	01	11	05	09	15	13	04	08	16	02	07	03	14	10	06	12	17	18
KL	12	05	13	16	02	10	08	03	01	15	06	04	07	14	11	09	17	18
RB	10	16	13	08	14	02	12	15	06	05	03	01	07	04	11	09	17	18
SB	11	09	15	04	02	12	14	16	01	03	06	10	08	13	05	07	17	18

ward movement, the subject could not maintain his head in the chin rest, so pupil data was not collected for this second startle response. These startle stimuli always occured at the end of the set of slides, and were always presented in the same order.

Data Collection

Method and Response Variables

One hour was assigned for processing each subject. Upon entering the Systems Lab, the subject was introduced to the experimenters, and was shown the equipment. The type of data to be collected was discussed in general terms. He was told that there would be time after the experiment to view the equipment in more detail and to see the charted results of his study. After filling out the pretest questionnaire, electrodes were attached to him and he was seated in the dentist chair. The electrodes were in turn attached to the Dynograph recorder. A light-sensing pressure clip for measuring systolic blood pressure was attached to the subject's right ear. The subject was asked to place his head in the chin rest and acclimate himself to the experimental apparatus.

While the subject was acclimating himself, the experimenters were adjusting the instruments and focusing the camera on the subject's left pupil.[2] As soon as all instruments seemed to be properly functioning,

[2] An interesting problem occurred when one subject noted that he was blind in the left eye. The camera was focused on the right eye, and no problems occurred as a result of this modification.

the subject was allowed to relax for a minute. He was then asked to readjust himself, and the 2-minute familiarization run was begun. After this run, the subject was allowed to relax for about 1 minute. During this minute, the carousels were rotated so that the stimulus and control slides were in position for the beginning of the main study. The tape recorder was recycled, and all equipment was checked for proper functioning. The main study followed this rest period.

Level of Measurement

While slides were being presented, continuous line chart recordings were being made on the Dynograph recorder. The Dynograph had a recording capacity of 6 channels. In order from top to bottom of the recording paper, the six variables recorded were: beat-by-beat heartrate; 60-second heartrate (extrapolated each second); pupil change; skin potential; blood pressure; and a light intensity reading for each slide, taken by a Weston Model 748 light meter installed inside the viewing box.

The BR-330 computer sampled the continuous data at a rate of 1 sample per second for each of the variables being recorded, thus providing a digital sample. Beat-by-beat heartrate was not sampled by the computer. A total of 2,560 samples was collected for each subject (512 samples for each of 5 response variables). These data were stored internally in the computer until the study had been completed, and were then transferred to punched tape. Later, the data were again transferred, this time to magnetic tape. Validation checks were made for each data reduction conversion, ensuring that errors in transfer were not made. Primary data analysis was done on the discrete data contained on

the magnetic tape. The punched tape data and chart data were used as back-up data sources, and were not subjected to much systematic analysis.

Post-Test Questionnaire

In an attempt to develop convergent validation of the autonomic responses (i.e., evaluate the character of each individual's autonomic responses from another type of measure) each subject was asked to complete a questionnaire rating the slides he viewed during the first part of the experiment. A copy of the questionnaire is included in Appendix I of the dissertation. This questionnaire was used as a major comparison index of affective responses to the slides. The correlation between this index and the pretest ratings made by independent judges was also computed.

Debriefing and Equipment Recycling

Since subjects were members of two student organizations, the possibility of discussion of the experiment prior to another subject's participation existed. Subjects were asked not to discuss the experiment with anyone, and were told that the investigator planned to give a debriefing and summary of the results to the group later in the quarter. Each subject was shown the chart output recorded during his participation, and the responses were explained to him.

While the subject was filling out the post-test questionnaire, the experimenters were transferring the data to punched tape, rearranging stimuli according to new random number sequences, resetting the computer and the rest of the equipment, and preparing for the next subject.

Data Transfer

The computer-gathered data sample was transferred from punched paper tape to magnetic tape and then to punched cards. Since this experiment was a pilot study on computer sampling, a great amount of time was consumed in the development of FORTRAN and machine language programs for converting and validating data gathered in octal (base 8) form on the paper tape to hexadecimal (base 16) form on the magnetic tape and then to decimal (base 10) form for analysis and presentation. These conversions involved the Mohawk tape-to-tape converter, the IBM 1620 and System 360/65 computers. The conversions from different bases were made necessary because of the utilization of the BR-330 computer and its data recording system. If real-time sampling with IBM equipment and direct magnetic tape or punched card output had been feasible for this study, the conversion process would have been less bothersome.

Data transfer and reduction programming took almost 2 months to complete. Now that the conversion packages have been "debugged" and validated, a complete data transfer from an "on-line" sample of 30 subjects during an experiment to decimal data ready for statistical analysis can be accomplished in less than 3 hours. If the System 360/65 had been used, or if a direct tie-in to the 360/65 through some type of terminal linkage device were used, data could have been transferred to a form ready for analysis in a matter of seconds from the time the data collection was completed. The advantages and disadvantages of such a real-time system, together with some cost/benefit data, will be discussed in a later section.

At each stage of the data conversion process, output data were compared with chart data recorded by the Dynograph recorder to ensure that errors had not been made. Several programming errors stemming from reversed polarity on the Dynograph recorder/BR-330 interfacing were detected using this technique. In most cases, these errors were correctable with minor modifications in the conversion programs.

Data Reduction

Several forms of data were analyzed. In almost all cases, the 10-second time span during which each stimulus was presented formed the basic period for analysis. Since the BR-330 served as both a director of the experiment (changing slides at given time intervals) and as a data recorder, it could not take samples during the second it was changing slides. Consequently, no data sample was taken during the first second after a slide change had occurred. This left a 9-second sample of each variable when a stimulus slide was presented, and a 19-second sample when control slides were presented.

Two basic measurements were used in defining types of responses. To test hypotheses on magnitude, the first measure compared absolute maximums during the relevant response period with absolute maximums during the prior control period. Second, percent change measures were incorporated. Using pupil size as an example,

$$\text{percent change in pupil size for stimulus } \underline{x} \text{ on presentation } \underline{a} = PCP = \frac{PD_{xa} - PD_{cxa}}{PD_{cxa}}$$

where PD_{xa} = mean pupil diameter during presentation *a* of stimulus *x* and

PD_{cxa} = mean pupil diameter during control period preceeding stimulus *x* on presentation *a*.

Regression coefficients were used to test differences in direction of responses, as discussed in later sections.

Two time periods were analyzed for each stimulus. A 3-second time span was analyzed because it was felt that the longer time periods conventionally used might be losing a substantial portion of the relevant pupil response due to a "damping" of the response over the long period. In this case, data collected in the first 3 seconds of each stimulus data sample were compared with data collected in the last 3 seconds preceeding the sample. The other time period involved a 9-second analysis, where data collected in the 9-second period following a stimulus were compared with data collected in the 9 seconds prior to the introduction of the stimulus.

Reduction in Sample Size

In several cases during the study, one or more problems occurred in the data sampling techniques. Several subjects, for example, had eyeblink rates which caused much of the data sample to be erroneous. In a few other cases, blood pressure and skin potential recording systems malfunctioned during the experiment, causing data on those variables to be lost. Consequently, for most of the analyses conducted, the sample size was reduced to 22, and the number of observations ranged from 270 to 470 per variable. These will be noted in the appropriate places in results discussed below.

CHAPTER V

RESULTS

As discussed in Chapter IV, the experiment incorporated a randomized block design, with 29 subjects serving as blocks and slide stimuli serving as randomized treatments. Most of the analyses discussed in this chapter utilized all 18 stimuli (16 slides and 2 "startle" stimuli) as treatments. Cases where the 18 were collapsed into 4 treatment groups (pleasant, unpleasant, neutral, and fear-arousing) will be discussed separately.

Analysis of Pupillary Reactions

A Linear Model of Pupil Response

In describing the pupil response to a given stimulus of the type used in this dissertation, the following linear model was developed:

$$PR = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8$$

$$+ \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \varepsilon$$

where PR = change in pupil size

β_i = regression coefficients

X_1 = the initial value of the pupil (base level)

X_2 = environmental sound changes

X_3 = environmental light changes

X_4 = the orienting reflex patterns of the pupil
X_5 = color patterns in the visual stimulus
X_6 = complexity of the stimulus
X_7 = interest value of the stimulus
X_8 = pleasantness/unpleasantness of the stimulus
X_9 = spot light intensities in the visual stimulus
X_{10} = scrambled light intensity of the stimulus
X_{11} = endogenous subject variables
ε = error term

As can be seen, the parameters of this very simplistic model emphasize that many things contribute to a given change in pupil size. The model served as a guide for controls used in the experiment and for the development of the set of linear predictors used in the statistical analysis. Better controls and the utilization of more accurate predictors should have caused an increase in the amount of explained variance in the dependent variable.

The model also emphasizes some findings which are not always considered in experimental designs and analyses. Most researchers, for example, have not taken adequate account of Wilder's Law of Initial Values, which states that a variable's "...response to stimulation is a function of the pre-stimulus level..." at which the variable was operating (Sternbach, p. 44). When using percent change as a dependent variable, an error is introduced when this law is not considered. For example, a pupil with a diameter of 7.5 millimeters has little potential for large dilation (the familiar ceiling effect) while it has a much higher propensity to constrict in size and return to a more normal

level of operation. A 2 percent dilation, therefore, might be much more significant at this level than a 10 percent dilation from a pupil which started out at a diameter of 3 millimeters. By using initial value as a predictor, and incorporating analysis of covariance, the model can "factor out" of treatment effects that part caused by initial values. Similarly, anxiety scores can be factored out by covariance when the effects of pleasantness-unpleasantness as a predictor are to be investigated.

The specific model used to test the experimental data was:

$$\begin{aligned} PR = {} & \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 \\ & + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} \\ & + \beta_{15} X_{15} + \beta_{16} X_{16} + \beta_{17} X_{17} + \beta_{18} X_{18} + \beta_{19} X_{19} + \beta_{20} X_{20} \\ & + \beta_{21} X_{21} + \beta_{22} X_{22} + \beta_{23} X_{23} + \beta_{24} X_{24} + \beta_{25} X_{25} + \beta_{26} X_{26} \\ & + \beta_{27} X_{27} + \beta_{28} X_{28} + \beta_{29} X_{29} + \beta_{30} X_{30} + \beta_{31} X_{31} + \beta_{32} X_{32} \\ & + \beta_{33} X_{33} + \beta_{34} X_{34} + \beta_{35} X_{35} + \beta_{36} X_{36} + \varepsilon \end{aligned}$$

where PR = 3 and 9 second percent change in pupil diameter

β_0 = 0

β_i = regression coefficients

$X_1 \ldots X_{36}$ were parameters described in Table 5-1

ε = an error term.

Table 5-1

Prediction Variables Used

Variable Number	Description	Type
1	3-second pupil percent change	dependent
2	9-second pupil percent change	dependent
3	initial value	moderator
4	slide 1	predictor
5	slide 2	predictor
6	slide 3	predictor
7	slide 4	predictor
8	slide 5	predictor
9	slide 6	predictor
10	slide 7	predictor
11	slide 8	predictor
12	slide 9	predictor
13	slide 10	predictor
14	slide 11	predictor
15	slide 12	predictor
16	slide 13	predictor
17	slide 14	predictor
18	slide 15	predictor
19	slide 16	predictor
20	3-second average---light intensity	moderator
21	9-second average---light intensity	moderator
22	questionnaire score---pleasantness	predictor
23	questionnaire score---interest value	predictor
24	interaction---light + initial value	predictor
25	interaction---interest val. + fav.	predictor
26	interaction---interest val. + iv	predictor
27	interaction---iv - light intensity	predictor
28	interaction---iv + fav	predictor

Table 5-1 (Cont.)

Variable Number	Description	Type
29	interaction---iv - interest value	predictor
30	interaction---interest value x lint	predictor
31	interaction---iv x fav	predictor
32	interaction---iv x interest value	predictor
33	interaction---light inten./iv	predictor
34	interaction---iv/fav	predictor
35	interaction---iv/interest value	predoctor
36	questionnaire score---anxiety	moderator

Several restrictions are inherent in the linear models approach adopted above. First, the assumption of linearity and linear effects may not be a good approximation of reality for physiological responses. Second, as can be seen in Table 5-1, analysis was limited to the first-order interactions of the model parameters. It does appear, however, that the data fit the parametric requirements necessary for the employment of the statistical techniques described below. As noted earlier, of particular concern was the time period between slides, since the experimenter wished to negate the impact of the previous stimulus slide on the response to the next-occuring slide. To test for serial effects, the Durbin-Watson test for auto-correlation (time series in the data) was utilized. The Durbin-Watson statistic ranged from 1.92 to 2.09 for all of the data used in the analysis, indicating that the 20-second time period between slides succeeded in eliminating the effects of the previous response.

Findings

A Spearman rank-order correlation (Siegel, 1956) between the questionnaire scores of independent judges and subject's questionnaire scores was computed in order to determine the agreement as to slide rank between the judges and the subjects in the study. The pleasantness-unpleasantness score was the variable investigated.

The subjects and pre-test judges tended to agree about the emotional content of the slides, yielding a correlation coefficient of 0.81 (significant at the .05 level). The rank order of the slides in the pre-test (independent judges) group never differed by more than 1 position from the rank order of the slides in the post-experimental (subjects) group. With one exception in the neutral category, the slides also maintained the same rank when compared by medians (nonparametric) or by the averages reported in Table 5-1. It can be inferred from the high degree of inter-rater reliability implied that a type of cross-validation of stimulus type has been accomplished.

Table 5-2 presents a summary of analysis of variance for the 4 general groups of slides used in the study. The differences here are also significant at the .05 level of confidence. As will be seen later, however, individual slide differences, when judged by the dependent variables, do not conform to the results hypothesized or to the results reported by proponents of pupillometric techniques.

Table 5-2

Analysis of Variance of Questionnaire

Results for 4 Groups of Slides

	Sum of Squares	D F	Mean Square	F Ratio
Between Groups	1130.2742	3	376.7581	3.3556
Within Groups	18638.0469	166	112.2774	
Total	19768.3203	169		

Tables 5-3 and 5-4 present summary statistics for stepwise regression with 3-second pupil change as the dependent variable. As can be seen, the model has a multiple correlation coefficient of 0.61, explaining 37 percent of the variability in the dependent variable. An analysis of the correlation coefficients associated with the independent and moderator variables yields no consistent relationship between the 4 stimulus types. When analyzed separately, the startle stimulus was the only one causing a consistent dilation in the pupil. It does appear that anxiety-arousing stimuli do cause significantly greater dilations than do other types of stimuli. No consistent findings were associated with pleasant, neutral, or unpleasant stimuli, as the tables show.

The 3-second time period, used in the present analysis, may cause part of the confusing results obtained. As Woodmansee (1965) has noted, the orienting and near-vision reflexes of the pupil cause a constriction in size. It may be that subjects allowed their eyes to lose focus during

Table 5-3

Last Step of Multiple Step-Wise Regression

Multiple R 0.6082

Std. Error of Est. 10.6773

Analysis of Variance	D F	Sum of Squares	Mean Square	F Ratio
Regression	21	16665.863	793.612	6.961
Residual	249	28387.078	114.004	

Variables in Equation

Variable	Coefficient	Std. Error	F to Remove
(Constant 0.0)			
4	-46.06	69.02	0.44
6	44.60	81.21	0.30
7	-88.76	150.53	0.34
8	-107.39	180.79	0.35
9	-69.47	118.22	0.34
10.	8.38	21.34	0.15
11	43.83	71.92	0.37
12	54.86	71.27	0.59
14	-28.15	37.41	0.56
15	40.32	60.27	0.44
16	-1.93	11.62	0.02
17	-21.35	39.67	0.28
18	-14.40	20.41	0.49
19	79.28	117.27	0.45
22	6.87	9.94	0.47
23	-39.13	63.11	0.38
24	-0.01	0.02	0.63
32	0.07	0.15	0.20
34	7.22	4.89	2.17
35	0.35	0.90	0.15

Table 5-4

Stepwise Linear Regression

3-Second Percent Change in Pupil Size

Step Number	Variable Entered	Multiple R	RSQ
1	28	0.446	0.199
2	12	0.490	0.240
3	16	0.523	0.274
4	24	0.548	0.360
5	10	0.558	0.312
6	4	0.570	0.325
7	18	0.582	0.339
8	5	0.587	0.345
9	6	0.593	0.351
10	14	0.597	0.357
11	19	0.599	0.359
12	34	0.600	0.361
13	30	0.602	0.363
14	17	0.603	0.364
15	36	0.603	0.364
16	11	0.603	0.364
17	remove	0.603	0.364
18	22	0.604	0.365
19	15	0.604	0.365
20	remove	0.604	0.365
21	7	0.605	0.366
22	32	0.605	0.366
23	35	0.605	0.366
24	remove	0.605	0.366
25	9	0.605	0.367
26	8	0.606	0.367
27	remove	0.606	0.367
28	13	0.606	0.367
29	remove	0.606	0.367
30	24	0.606	0.368
31	remove	0.606	0.368
32	14	0.607	0.368
33	remove	0.607	0.368
34	19	0.607	0.368
35	remove	0.607	0.368
36	23	0.607	0.369
37	11	0.608	0.369

the 20-second control period between slides, and then had to refocus when a new slide appeared. The near-vision reflex associated with refocusing would explain at least part of the results found.

Tables 5-5 and 5-6 present the results obtained from the regression with the 9-second percent change in pupil size as dependent variable. The multiple correlation coeffficient, and consequently the explained variance, is lower for this model. Again, the results of individual slide regressions are equivocal. As before, analysis of covariance should have eliminated the effects of light intensity and initial value on the final results. These findings raise questions about our ability to deduce any meaningful conclusions from results of pupillometric assessment studies. The low explained variability, together with the inconsistency associated with responses to the 4 types of stimuli, raises many questions about the usefulness of pupillometric techniques.

The following tables present results of stepwise linear regressions on heartrate, blood pressure, and skin potential. As would be expected in models which do not lag these variables, the multiple correlation coeffficients and explained variance are lower than those for the pupil response equations.

Table 5-5

Last Step of Stepwise Multiple Regression

Dependent Variable: 9-Second Pupil Change

Multiple R 0.5757

Std. Error of Est. 11.0520

Analysis of Variance	D F	Sum of Squares	Mean Square	F Ratio
Regression	22	15019.426	682.701	5.589
Residual	248	30292.547	122.147	

Variables in Equation

Variable	Coefficient	Std. Error	F to Remove
(Constant 0.0)			
4	303.63	221.85	1.87
5	202.32	150.13	1.81
6	-18.28	13.92	1.72
7	435.78	311.09	1.96
8	502.98	358.59	1.96
9	418.95	300.54	1.94
10	101.59	80.75	1.58
12	64.58	37.99	2.88
13	114.04	74.78	2.32
14	124.12	76.93	2.60
15	78.31	55.24	2.00
16	120.62	96.69	1.55
17	291.01	212.84	1.86
18	246.07	182.02	1.82
21	-0.06	0.12	0.27
23	110.46	74.74	2.18
26	-18.92	16.60	1.29
28	19.92	15.65	1.62
31	-0.02	0.00	8.95
32	-0.26	0.13	4.00
33	-517.40	970.02	0.28
35	-0.86	0.74	1.34

Table 5-6

Stepwise Linear Regression
9-Second Percent Change, Pupil Size

Step Number	Variable Entered	Multiple R	RSQ
1	16	0.318	0.101
2	10	0.416	0.173
3	12	0.445	0.198
4	28	0.487	0.237
5	26	0.501	0.251
6	13	0.509	0.259
7	19	0.516	0.266
8	16	0.524	0.274
9	9	0.533	0.281
10	32	0.5354	0.286
11	21	0.539	0.291
12	31	0.557	0.311
13	33	0.564	0.318
14	4	0.567	0.322
15	23	0.568	0.323
16	17	0.569	0.324
17	8	0.570	0.324
18	35	0.570	0.325
19	14	0.571	0.326
20	7	0.571	0.326
21	18	0.571	0.326
22	5	0.571	0.326

Table 5-7

Correlations Between Pupil Change and Stimuli

Variable	3-Second Percent Change	9-Second Percent Change
1. 3 sec %	1.0	0.81
2. 9 sec %	0.81	1.00
3. Initial Val	-0.38	-0.25
4. Dog	-0.14	-0.08
5. Baby	-0.08	-0.05
6. Animal	-0.17	-0.10
7. Baby	0.00	-0.02
8. Baby	0.02	0.03
9. Baby	0.04	0.08
10. Triangle	-0.22	-0.27
11. Girl	-0.07	-0.13
12. Chair	+0.10	+0.15
13. Nude	-0.08	0.00
14. Girl	-0.15	-0.11
15. Block .	-0.05	0.01
16. Rectangle	-0.30	-0.31
17. Child	-0.01	-0.01
18. Hanging	-0.16	-0.08
19. Woman	-0.03	-0.02
20. Startle	+0.32	+0.21

Table 5-8

Summary by Stimulus Groups of
3-Second Heartrate Regressions

Step Number	Variable Entered/Removed	Multiple R	RSQ
1	6	0.155	0.024
2	3	0.172	0.029
3	7	0.196	0.038
4	5	0.202	0.040
5	4	0.357	0.128

Variables are: 3 - Initial Value

4 - Pleasant Stimuli (in groups)

5 - Neutral Stimuli (in groups)

6 - Unpleasant Stimuli (in groups)

7 - Anxiety Arousing Stimuli (in groups)

Table 5-9

Summary by Individual Stimuli:

Stepwise Linear Regression with
9-Second Heartrate as Dependent Variable

Step Number	Variable Entered/Removed	Multiple R	RSQ
1	3	0.426	0.181
2	21	0.445	0.198
3	13	0.460	0.212
4	9	0.473	0.223
5	18	0.484	0.234
6	5	0.494	0.244
7	10	0.500	0.250
8	16	0.507	0.257
9	17	0.511	0.261
10	14	0.515	0.265
11	7	0.517	0.267
12	4	0.518	0.269
13	20	0.520	0.270
14	15	0.520	0.270
15	12	0.520	0.270
16	8	0.520	0.271
17	11	0.521	0.271
18	19	0.521	0.272
19	remove	0.521	0.272
20	6	0.523	0.274
21	20	0.528	0.279

Variable 3 is Initial Value
Variables 4-21 are individual slide and startle stimuli

Table 5-10

Summary by Stimulus Groups

9-Second Percent Change in Heartrate

Step Number	Variable Entered/Removed	Multiple R	RSQ
1	3	0.427	0.182
2	5	0.439	0.193
3	6	0.444	0.197
4	7	0.445	0.198
5	4	0.458	0.210

Variables are:

3 - Initial Value

4 - Pleasant Stimulus Group

5 - Neutral Stimuli Group

6 - Unpleasant Stimulus Group

7 - Anxiety-Arousing Stimulus Group

Table 5-11

Summary by Stimuli

Stepwise Linear Regression of
3-Second Percent Changes in Blood Pressure

Step Number	Variable Entered/Removed	Multiple R	RSQ
1	20	0.097	0.009
2	14	0.127	0.016
3	9	0.148	0.021
4	17	0.165	0.027
5	19	0.174	0.030
6	4	0.178	0.031
7	3	0.179	0.032
8	15	0.180	0.032
9	5	0.180	0.032
10	6	0.181	0.032
11	8	0.182	0.033
12	18	0.182	0.033
13	16	0.183	0.033
14	21	0.183	0.033
15	7	0.183	0.033
16	10	0.183	0.033
17	13	0.183	0.033
18	11	0.184	0.033
19	12	0.184	0.033

Variable 3 is initial value
Variables 4-21 are stimuli

Table 5-12

Stepwise Linear Regression of
9-Second Percent Changes in Blood Pressure

Step Number	Variable entered/removed	Multiple R	RSQ
1	21	0.115	0.013
2	15	0.162	0.026
3	8	0.191	0.036
4	19	0.200	0.040
5	4	0.208	0.043
6	14	0.212	0.045
7	3	0.214	0.046
8	18	0.215	0.046
9	6	0.215	0.046
10	10	0.216	0.046
11	17	0.216	0.046
12	9	0.216	0.047
13	20	0.217	0.047
14	5	0.217	0.047
15	7	0.217	0.047
16	12	0.217	0.047
17	11	0.217	0.047
18	16	0.217	0.047
19	13	0.217	0.047

Variable 3 is initial value
Variables 4-21 are stimuli

Table 5-13

Stepwise Linear Regressions of
9-Second Percent Changes in Skin Potential

Step Number	Variable Entered/Removed	Multiple R	RSQ
1	11	0.205	0.042
2	12	0.275	0.075
3	16	0.298	0.089
4	17	0.299	0.089
5	4	0.299	0.089
6	7	0.300	0.090
7	14	0.300	0.090
8	9	0.300	0.090
9	6	0.301	0.090
10	19	0.301	0.090
11	21	0.301	0.090
12	18	0.301	0.090
13	20	0.301	0.090
14	5	0.301	0.090
15	13	0.301	0.091
16	3	0.301	0.091
17	15	0.301	0.091
18	10	0.301	0.091
19	8	0.301	0.091

Variable 3 is initial value
Variables 4-21 are stimuli

Note: Because of the response latency in skin potential, 3-second changes were not analyzed.

The results described above were applied to the hypotheses listed in Chapter II. Hypothesis 1, "pleasant stimuli will be accompanied by dilation, while neutral stimuli will cause no change in pupil size", was not supported. As can be seen in the correlation matrix presented in Table 5-7, all pleasant stimuli have a slight negative correlation with 3-second pupil change. Although the correlations were less negative for the 9-second pupil change data, they are still negative. Similarly, neutral stimuli generally had negative correlations. These resutls include the factoring out of anxiety scores by analysis of covariance.

Hypothesis 2, "negative stimuli will cause a constriction of the pupil", was not supported, since the pupil reaction to these stimuli was largely a positive change in size. Hypothesis 3, "anxiety-arousing stimuli will dilate the pupil", was supported.

Hypothesis 4 could not be tested due to the inconsistencies in the response to pleasant stimuli. Since no consistent response to pleasant stimuli was found, the degree of dilation could not be compared with dilations associated with anxiety stimuli. Hypothesis 5, "highly pleasurable stimuli will produce greater pupil dilation than will less pleasant stimuli", was not supported, as the correlation matrix shows.

Some positive results were obtained in the analysis of magnitude covariance. Hypothesis 7, "blood pressure changes will be similar in reaction when exposed to pleasant stimuli and when exposed to anxiety-arousing stimuli", was not supported. While blood pressure showed no

consistent relationship to positive stimuli, it did show a positive relationship to anxiety-arousing stimuli, with a lag of several seconds. Heartrate decreased as a response to startle stimuli, while showing no consistent response to pleasant stimuli, so hypothesis 8, "heartrate changes will be similar when exposed to anxiety-arousing stimuli and pleasant stimuli", was not supported. Skin potential had the largest time lag (between 6 and 10 seconds) to startle stimuli, and had fairly large magnitude changes (up to 70 percent). It showed no consistent relation to pleasant stimuli, so Hypothesis 9 was not supported.

Hypothesis 10 could not be tested, again due to the inconsistency in responses to pleasant stimuli. Hypothesis 11 was supported, since no consistent relation between heartrate and positive stimuli were found, while the average time from beginning of a startle response to its end was 6.2 seconds. Hypothesis 12 was not supported, since no consistent relationship was found for response latency or return of skin potential to either type of stimuli. Hypothesis 13 was supported, probably because of the relationship existing between heartrate and blood pressure.

Table 5-14 presents a summary of the hypotheses and the results obtained.

Table 5-14

Results by Hypothesis

Hypotheses	Supported/Rejected
Pupillary Reaction	
1. Pleasant stimuli will be accompanied by dilation, while neutral stimuli will cause no change in pupil size.	not supported
2. Negative stimuli will cause a constriction of the pupil.	not supported
3. Anxiety-arousing stimuli will dilate the pupil.	supported
4. Anxiety-arousing stimuli will cause greater dilation than will pleasant stimuli of the same intensity.	*
5. Highly pleasurable stimuli will produce greater pupil dilation than will less pleasant stimuli.	not supported
6. Highly negative stimuli will produce greater pupil constriction than will less negative stimuli.	not supported
Autonomic Contamination	
A. Magnitude Covariance	
7. Blood pressure changes will be similar in reaction when exposed to pleasant stimuli and when exposed to anxiety-arousing stimuli.	not supported
8. Heartrate changes will be similar when exposed to anxiety-arousing stimuli and pleasant stimuli.	not supported
9. Skin potential changes will be similar in reaction when exposed to anxiety-arousing and to pleasant stimuli.	not supported
B. Response Duration	
10. Pupillary dilation to anxiety-arousing stimuli will take longer to return to initial base level (at time of stimulus presentation) than will pupil dilation to pleasant stimuli, for a given level of stimulus intensity.	*

---

*Untestable with present data

Table 5-14 (Cont.)

Hypotheses	Supported/Rejected
11. Heartrate will take longer to return to base line in response to anxiety-arousing stimuli than to pleasant stimuli, for the same stimulus level.	supported
12. Skin potential will take longer to return to base line in response to anxiety-arousing stimuli than to pleasant stimuli, for the same stimulus level.	not supported
13. Blood pressure will take longer to return to base line in response to anxiety-arousing stimuli than to pleasant stimuli, for the same level of stimulus intensity.	supported

Shortcomings

It would be useful to attempt to explain the disheartening results described above as the product of poor experimental design or analysis. The controls used in the study, however, were at least as rigorous as most reported in the literature. Also, as mentioned previously, the data were collected in 2 forms (chart and digital) with chart data being used to validate digital data at all points of conversion, so data reduction errors seem to be negligible.

Although the steps taken speak well for the data collected, there are several areas where the experiment could have been improved. Better care could have been taken to develop a set of slides with more closely balanced light intensities. Spot intensity on each slide should have

been controlled. At the data recording level, better measures of light intensity could have been made.

It appears that the scores on the pre-test questionnaire may have led to erroneous conclusions about one or more slides. For example, the slide showing an attacking police dog scored highest on the anxiety-arousing dimension, and was therefore included in the anxiety set. Subjects who were debriefed informally, however, tended to agree that there was little anxiety-arousing quality in a slide of an attacking dog, so the questionnaire score may have been misleading.

The method by which eyeblinks were edited in the computer data could also be improved. The data reduction programs incorporated a subroutine whereby each reading under 2.5 millimeters was eliminated and the data point immediately preceeding the eyeblink was substituted. Perhaps the most appropriate procedure would have been the total elimination of that data point. Alternatively, several smoothing techniques are available which would have been more appropriate than the method used.

CHAPTER VI

METHODOLOGICAL IMPROVEMENTS: THE FEASIBILITY OF COMPUTER CONTROL AND DATA SAMPLING

As discussed in previous chapters, the methods of data collection in psychological and medical research on physiological variables are often tedious and subject to several types of error. One of the most productive results of this study was the demonstration that computer sampling is a viable and advantageous method for collecting data on physiological variables. Computers today are capable of performing many different functions, and are available in many forms and sizes. Their costs are now at a level where most researchers should take time to examine their usefulness.

Advantages

Several advantages accrue to the researchers who utilize the computer. If he can develop a method whereby the computer can be programmed to control the presentation of stimuli, as in this study, the experimenter can significantly reduce the uncertainty and inconsistency with which humans perform such activities. The computer can overcome limitations of human performance capabilities, such as the split-second changing of slides in the present study. Because of their high pro-

cessing speeds, computers are capable of performing several operations simultaneously, such as the changing of slides and collection of several data samples in the span of a second.

As a data collector, the computer offers the advantages associated with unbiased sampling and recording of results. As the experimenter has shown earlier (Bell, 1971), controls of this type must be incorporated in physiological data-gathering methods. Computers also provide a significant reduction in the time it takes to produce data in a form ready for analysis.

Perhaps one of the major advances in computer hardware in recent years has been the mini-computer. These machines, incorporating solid-state microcircuitry, can be obtained in sizes that will fit almost anywhere, and that are highly adaptive to the specific requirements of the purchaser. Vendors will, in some cases, assist in the acquisition of equipment configurations which best meet the needs of the user. Several mini-computers are "conversational" (have the ability to communicate) with larger scale machines. A physiological researcher could obtain a PDP-11 mini-computer (Digital Equipment Corporation), for example, to control his experiment and collect his data. The machine could be connected via phone link to a large-scale system such as the IBM 360/65 where direct data reading and analysis could take place. Thus the machine at the local level could be adapted to a specific research need, while maintaining the ability to use large-scale data analysis

packages, and all of the peripheral equipment associated with the larger scale systems.[1]

Finally, many persons associate the word computer with high costs of operation, while not fully realizing that computer utilization may reduce or eliminate other costs related to the project. This will be discussed in more detail later in this chapter.

Disadvantages of Computer Usage

One of the major disadvantages of computer usage to behavioral researchers is the dependence on the "systems man" such usage creates. Before a system can be utilized, hardware must be acquired and made operational, and software (programs) must be developed and debugged. Once the system is operational, any changes to be made or any errors to be corrected require that someone familiar with the computer be called in.

There may also be a tendency to accept the face validity of computer-generated data without questioning the data collection, transfer, and analysis. When using the computer, an experimenter can be far removed from the data he is collecting, and may miss important happenings during the experiment that could influence the data. The use of a computer does not relieve the experimenter of the responsibility for accurate

[1]The use of an earlier model Digital Corporation Machine, the PDP-8, in clinical and diagnostic medical research has been described earlier by Covvey (1970).

data collection, analysis, and reporting. An important consideration is the frequency and complexity of the projects to be undertaken by the computer. Computers make costly pieces of furniture in a research laboratory if the extent of their usage does not justify their acquisition. In university settings, researchers many times share a computer with others who need one in order to reduce the per-project utilization costs.

Some Cost-Benefit Considerations

It is a relatively simple matter to discuss the advantages and limitations of computer systems in general terms. Before the recommendation to purchase a system can be accepted or rejected, however, the very difficult task of assigning dollar costs and benefits of the system must be undertaken. Many cost figures can be readily obtained from price lists of manufacturers. Others, such as the cost of installing the system and making it operational, are less easy to pinpoint, and may require a great deal more research and "guesstimation". Even these, however, may be estimated from the files of users of similar equipment, or from the manufactuer.

The most difficult problem lies in the generation of accurate estimates of the benefits to be derived from the computer system. Before the system is installed, it is impossible to foresee all of the possible applications it may have. It may also happen that some anticipated uses

of the system are not realized after installation. About the best that can be done is an attempt to foresee as many potential advantages (and limitations) as possible, and to treat these data in a way that recognizes the uncertainty under which they were generated. For this reason, this section will treat data in a manner proven useful in other situations involving uncertainty. In particular, when uncertainty exists, data will be derived from the familiar weighted-average formula used in PERT and other project planning and control techniques.[2]

A computer system for collecting and analyzing data of the type described in this disseration, would at a minimum, contain elements for acquiring, storing, and processing data. The hypothetical system described below attempts to realistically meet those requirements within the framework of decisions made by a university researcher. It is assumed that the researcher is now collecting data manually (as most pupillometric researchers do), transferring it to punched cards and analyzing it by computer.

It is further assumed that measuring instruments such as the television pupillometer and devices for assessing heartrate, blood pressure, and skin potential are readily available. A central processng unit (C.P.U.) with at least 4-thousand (4-k) bit memory would be required to store the data. Analog-to-digital conversion requirements call for

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[2]Wallace, J.B., "Improving communication between systems analyst and user", Data Management, June 1972, pp. 21-25.

the purchase of 6 channels of converters, and the input/output operations of the system require a 4-k 16-bit read/write computer core.

The hardware described above form the nucleus for a system capable of acquiring and storing an amount of information comparable to that gathered for each subject in this dissertation. If we assume that the system is being designed for a university research laboratory, then the most efficient use of additional funds for analysis data equipment would be the purchase of a dataphone. This would allow the computer to communicate with a larger-scale system. The dataphone would tie the small computer in with the C.P.U. of the larger machine, thus greatly enlarging the storage capacity of the system, increasing its analytical capabilities, and connecting it to all of the peripheral devices on the larger system.

Table 6-1 describes the dollar estimates of annual benefits to be gained from the new computer system. Table 6-2 describes estimated costs. Estimates were made by this writer and by a professor currently engaged in psychiatric research using pupillometrics and heartrate analysis. Some of the sources of dollar cost reductions or added benefits are mentioned briefly in the tables.

As can be seen, the simple ratio of annual benefits of the new system to annual costs is 0.30 . Several other techniques for analyzing cost and benefit data are currently used. Among these, the cost/benefit ratio and payback period for the investment in the computer system were computed.

Table 6-1

PDP 11/20 System with Dataphone Linkage to IBM 360/65

Cost/Benefit Analysis

(Annual Basis)

Benefits:	
Reduction & Reassignment of Clerical Staff	
(Reduction in staff needed to measure physiological variables)	
(Reduction in keypunch costs)	$ 8,000
Responsiveness: Faster Data Transfer	
(ability to spot errors while subjects and equipment configurations are still available)	1,000
Accuracy: Increase in Reliability of Data Sampling	
(value of increased accuracy: reduced need to reperform experiment; increase in confidence in generating reports, etc.)	1,000
Comprehensiveness: Capability for Increased Scope of Data Acquisition	
(value of additional information; value of new projects won because of expanded capabilities)	5,000
Total Estimated Annual Benefit	$15,000

Cost/Benefit Estimates Derived from Beta-Distributed Estimates Under Uncertainty:

$$E = \frac{O + 4ML + P}{6}$$

where P = pessimistic

O = optimistic

ML = most likely

Table 6-2

PDP 11/20 System with Dataphone Linkage to IBM 360/65

Cost/Benefit Analysis*

(Annual Basis)

Costs	
Nonrecurring	
C.P.U. Purchase	
4-K 16-bit read/write memory	
Programmer console	
Basic mounting box	
Power supply	
ASR-33 teletype and control	$ 10,800
4 K 16 bit read/write core	3,000
A to D converters, 6 channels	2,700
Dataphone	1,800
System installation/debugging	1,000
	$ 19,300
5-year life - Annual Basis	3,860
Recurring	
Dataphone Modem Rental ($100/mo.)	1,200
System programming	2,000
System maintenance	1,000
System supplies	500
CPU time/System 360	5,000
Total estimated annual cost	13,560
Cost divided among three projects	4,520

Cost/Benefit Estimates Derived From Beta-Distributed Estimates Under Uncertainty:

$$E = \frac{P + 4ML + O}{6}$$

where P = pessimistic; O = optimistic; ML = most likely

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*Source: Digital Equipment Corporation: PDP 11/20 Price List, Nov.1970

The payback period is defined as:

$$\frac{\sum_{k} CI_k}{\sum_{j} \left(\sum_{j} B_{j,t} - \sum CC_{i,t} \right) / T}$$

where
- T = expected life of the system
- B = the jth benefit in time period t
- CC = the ith recurring cost in time period t
- CI = the kth initial cost
- R = the time value of money or cost of capital

For the data described in Tables 6-1 and 6-2, the payback period is 1.58 years. These data indicate that the system will pay for itself in approximately one and one-half years. Since a 5-year life was assumed, it appears that these results indicate that investment in the system is justified.

The cost/benefit ratio is computed from the formula:

$$\frac{\sum_{t} (\Sigma B - \Sigma CC)}{(1 + R)^t} \bigg/ \Sigma CI \quad .$$

The data yield a cost-benefit ratio of 0.424, indicating that over the 5-year period the costs associated with the system, even when considering the time-value of money invested, are less than one-half of the generated benefits. These results also support arguments for acquisition of the system.

As is obvious, the data presented in Table 6-1 represent very uncertain estimates of benefits. However, even if we can assign only a probability of 0.50 to the expected occurence of these benefits, the cost/benefit ratio still is less than 1.0. This result allows some degree of confidence in the statement that a system can be justified.

In summary, it appears that researchers should investigate possibilities computer systems offer as sources of more advanced experimental control and analysis. Although specific cost and benefit figures depend on individual project requirements, the data presented above suggest that, in some cases, investments in these systems can be easily justified.

CHAPTER VII

IMPLICATIONS FOR FUTURE RESEARCH

The results of this study raise several questions about the direction of future research on pupillometrics. If we accept the hypothesis that the pupil does respond differentially to stimuli and that it could be a useful indicator of emotional reactions, then we are faced with the apparent need for much more basic and much more intensive work than has been previously reported. As with this dissertation, for every "positive" finding reported in the pupillometric literature, there seems to be a corrolary "negative" one. Until this type of research reaches a stage where general uniformity of results is accomplished, it will not be accepted as a useful technique for more advanced applications.

Attitude Theory

Given the complexity of design necessary for evaluating attitudes with physiological variables, an effort should be made to determine the additional information this design yields over other, more conventional, measures of attitudes. It appears that paper-and-pencil instruments such as the semantic differential, the Likert technique, or the Thurstone technique would yield more information per input unit of work expended that would the physiological techniques. At the present state of the art

in pupillometrics, it also appears that these scales would yield a greater absolute magnitude of information than would pupil studies. The generally reported reliability and validity coefficients associated with the paper-and-pencil methods are higher than those associated with pupillometrics (Woodmansee, 1965), so it appears that for most assessment problems, the conventional measurement instruments may be more appropriate.

Comparative studies along this line could define some relevant attitude domain to be sampled, then develop assessment instruments of both types, noting the costs of development in time, dollars, manpower, and other resources expended. Reliability and validity coefficients could be computed using data gathered from "known groups". Per unit contribution and absolute contribution of information could be calculated for each technique.

Research on Stimulus Presentation

Perhaps one of the most limiting factors in pupillometrics is the method of operationalizing independent variables through visual stimuli. A look back to the regression models developed in Chapter V demonstrates this problem. Many of the factors affecting pupil size are associated with the eye as an input medium for stimuli. The near vision reflex, the orienting reflex, color adaptation, light intensity (both spot and scrambled), stimulus complexity, and the physical location of the visual stimulus all cause changes in pupil size. If it were possible to develop

a different type of stimulus input, such as auditory stimulation, the large number of contributors to pupil change would be reduced, and perhaps the effects due to stimulus content could be better isolated.

Beyond this problem, there is the difficulty of projecting attitude objects through the use of visual stimuli. As several subjects in the present study noted, a very large difference exists between an attacking police dog and a picture of an attacking police dog. Similarly, a picture of a Negro may not evoke the same type of response that a living being does.

A very difficult problem must be overcome before pupillometric techniques can be applied in areas such as the personnel function. To date, most successful studies have involved fairly simple, basic attitudes. Most of these could have been evaluated equally well using conventional techniques. The hope is that some method for presenting complex emotional stimuli can be developed. Of all stimulus types, complex visual stimuli are the least preferred, since the complexity requires greater coping behavior from the pupil and causes greater eye search of the stimulus, both of which confound pupil change data. Some method which does not cause confounding interactions with the dependent variable must be developed for presenting more complex stimuli.

Field Research

In the marketing area, in addition to research in stimulus presentation, much work needs to be done on equipment and mobility. Present

techniques are still very "obtrusive" and interactive with the respondent. The development of a non-interactive measuring instrument for research on consumer's reactions to package design and other promotional techniques would be a major advance.

If marketing researchers plan to use pupillometrics, a useful study could be made using portable physiological recording devices. A physiological recorder, for instance, could record several tracks of data simultaneously, during a marketing study. The data could then be taken back to the laboratory and read directly from the recorder into a computer. The lag time between data collection and analysis could be significantly reduced using this technique. Researchers could evaluate the tradeoffs between using still-frame versus video cameras, and could develop cost/benefit analyses of the instruments used in the study.

Laboratory Research

Much work still needs to be done in the area of instrumentation in pupillometric research. It appears that there is very little question, other than relative costs, about the general superiority of video systems such as the television pupillometer, especially when such systems can be interfaced with a computer. Whether the significant additional costs of the television system are justified depends upon the value of the information to be gathered and the availability of supporting equipment.

Finally, applications of the mini-computer in physiological research can now be evaluated. Work needs to be done on the compatibility of the small computer systems with larger systems. The information processing, storage, and input/output requirements of physiological data processing systems need to be investigated. With advances in computer technology continuing at the current rate, researchers who do not recognize the potential of the computer for their projects may soon be left with obsolete methods and inferior results.

CHAPTER VIII
SUMMARY AND CONCLUSIONS

Goals

The goals of this dissertation were to replicate findings that pupil change is a useful measure of emotional reactions to visual stimuli, develop a linear model explaining the contributors to pupil change, develop a computer sampling method and examine the feasibility of its use in pupil change studies, and study the other physiological covariates in pupil change. It was hoped that the recording of changes in other variables along with pupil change would lead to a means of discriminating between pupil dilations caused by pleasurable stimuli and dilations caused by anxiety-arousing stimuli.

Method

Fourteen males served as independent raters of 57 slide stimuli. Of the 57, 16 were chosen for use in the study. The 16 were divided into 4 visual stimulus categories: pleasant, neutral, unpleasant, and anxiety- or fear-arousing. The medians test was used to test for differences between the sets of stimuli. Each set was significantly different from the other sets at the .01 level. It appears, however, that the slide used as an anxiety-arousing stimulus was actually not capable of arousing

anxiety in the subjects used. Two startle stimuli--a buzzer and a drop of several inches in the chair subjects sat in--were also included in the anxiety set.

The study took place in a laboratory where environmental light and sound levels could be controlled. Subjects were seated in a dentist's chair, and looked into an apparatus similar to a Hess Box. Slides were presented in random order on a screen at the end of the box opposite the subject. The two startle stimuli always occurred as stimuli number 17 and 18.

A television pupillometer measured change in pupil size. In addition, heartrate, blood pressure, and skin potential were measured. These variables, together with the light intensity of the slide screen, were recorded with a Dynograph recorder, which produced charts of the data for each subject.

The Bunker-Raymo computer was connected with analog-to-digital converters to the Dynograph recorder and recorded second-by-second digital readings for each of the variables. At the end of each session with a subject, a paper tape record of the 2,560 readings taken on that subject was produced.

A Bunker-Raymo process control computer was connected to two Kodak carousel 850 slide projectors and controlled the timing of the slide presentations. Each stimulus slide was preceeded by a 20-second blank slide. The Bunker-Raymo, by initiating a change in the projector containing the stimulus slide before removing the controls slide, reduced

the light-flash and time required to change slides to under 1/10 second. At the end of the slide sequence, the computer automatically sounded the buzzer. Approximately 20 seconds later, the experimenter released the vertical hold of the chair the subject was sitting in, causing it to "fall" rapidly for about 5 inches.

Analysis

The paper tape record was converted to magnetic tape, and the magnetic tape data were analyzed. For analytic purposes, a linear model was used to describe the parameters affecting pupil change. Stepwise linear regressions were computed for each of the physiological variables, with the regressions using analysis of covariance to negate the effects of light intensity changes and the effects of base level --the "initial value" of the dependent variable before stimulation. In addition, correlations between each slide and the percent change in pupil size were computed, using both a 3- and a 9-second measurement of pupil change.

Analysis of variance of pupil change was computed for the 4 groups of stimuli. Other, more general analyses involved an investigation of the time lags associated with the physiological variables, and an analysis of consistencies in response magnitudes.

Results

Although 36 variables, including first-order interactions, were included in the stepwise regression analysis, and although the model's

predictability of pupil change was significant at the .05 level, the explained variance in pupil size was less than 40 percent. Furthermore, although analysis of variance for the groups of stimuli was significant at the .05 level, the individual correlations of slides with the dependent variables were low and surprisingly inconsistent. Pleasant slides did not produce consistent pupil dilation. In fact, just the opposite was true in many situations. Using pupil change as a predictor, researchers would have failed to identify the sets of slides chosen by the independent raters. Since post-test questionnaires filled out by subjects tended to agree with the independent judges as to the classification of slides, the hypothesis that pupils dilate to pleasant stimuli and constrict to negative stimuli does not find support in these data.

Because of the discrepancies in direction of pupil change, certain hypotheses about the relative effects of pleasant and anxiety-arousing stimuli on pupil dilation could not be tested with the data gathered.

It does not appear, on the basis of response latency data and magnitude data, that heartrate would be a useful covariate indicating an anxiety-arousing stimulus. Further work could be done on the length of time from stimulation to maximum response as a possible indicator of strength of reaction.

Cost/Benefit Analysis

A brief cost/benefit study was conducted to determine the feasibility of using mini-computers as real-time data sampling instruments in the type of research reported in this dissertation. Many advantages of

computer usage were cited, including increased data reliability, increased experimental control, faster turn-around of data, and the potential for expansion of the scope of research projects. Costs, inefficient usage, and the dependence on systems programmers were discussed as drawbacks to the adoption of computer-based techniques.

Although specific data were not available in every category, the experimenter, a laboratory technician, and a full-time researcher made estimates of some of the costs and benefits associated with computer usage. Estimating techniques for decisions under uncertainty were used to calculate final figures. Results indicate that there are significantly more dollar benefits than dollar costs, and that, at least in some instances, computers can be justified as laboratory instruments.

Conclusions

With the large amount of data collected in this study, comprehensive analysis has just been initiated by the dissertation report. The disheartening results so far seem to indicate that the basic theory proposed by Hess and others is open to significant question. It appears at this stage as if the results reported previously have been contaminated due to lack of adequate consideration of such factors as stimulus visual complexity, initial levels of response variables, interactions of response variables, and the myriad of within-subject contributors to physiological changes.

Also, for the pupillometric technique to be useful to business researchers, a great deal more consistency in the response variables must

be found. This study, together with others such as those by Woodmansee (1965) and Nunnally, et al. (1967) tends to indicate that this may be a very difficult task.

In addition, it appears that visual stimuli are less-than-optimal for use in pupil studies. The use of the eye as both an input and an output mechanism is of questionable value. Many of the "contaminants" of the pupillary response to psychological stimuli are associated with visual presentation. The care with which stimuli must be produced, together with the problem of operationalizing complex emotional stimuli through pictures, indicates that new directions of research on methods of stimulus presentation are needed.

Although concentrated analysis has yet to be done, it appears that all other physiological variables studied hold some hope of serving as indicators of the autonomic contamination reported by Hess. Their usefulness, of course, presupposes pupil dilation to both pleasant and fear-arousing stimuli--a supposition not supported by the findings reported here.

The ease with which computer data sampling was accomplished indicates that this technique could prove very useful to researchers. The efficient use of a computer, however, requires a well-equipped laboratory with sophisticated measuring devices such as the television pupillometer. In view of the present state of the pupillometrics art, however, it appears reasonable to assume that researchers will have to use advanced techniques to avoid the collection and presentation of spurious results.

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APPENDICES

APPENDIX I: Pre- and Post-Test Questionnaires

Slides Pretest

Slide number: ____________________ Describe it: ________________________

Look at what is going on in the picture. How does it make you feel?

Use the middle of each scale as a "neutral" position, with your reaction getting stronger as you move farther toward the end points of the scale. Place one mark on each line.

How does this slide make you feel?

Afraid	___	___	___	___	___	___	___	Unafraid
Calm	___	___	___	___	___	___	___	Nervous
Disgusted	___	___	___	___	___	___	___	Elated
Secure	___	___	___	___	___	___	___	Insecure
Gloomy	___	___	___	___	___	___	___	Cheerful
Tense	___	___	___	___	___	___	___	Relaxed
Hostile	___	___	___	___	___	___	___	Friendly
Upset	___	___	___	___	___	___	___	Contented

How would you evaluate the slide in terms of the following characteristics?

Pleasant	___	___	___	___	___	___	___	Unpleasant
Unfavorable	___	___	___	___	___	___	___	Favorable
Interesting	___	___	___	___	___	___	___	Uninteresting
Negative	___	___	___	___	___	___	___	Positive

Post-Test Questionnaire

To be completed immediately after viewing slides

Your Name ______________________________ Number ____________________

We would like you to look at copies of the slides you have just seen. We would like to know how each of them made you feel when you viewed them a few minutes ago. Please take as much time as you want, and fill out one answer sheet for each slide. When you have finished evaluating that slide, advance the projector to the next one and fill our an answer sheet for it.

Answer Sheet

Slide Number: ________________

Describe the slide: ____

How did this slide make you feel? Use the middle of each scale as a "neutral" position, with your reaction getting stronger as you move farther toward the end points of the scale. Place <u>one</u> <u>mark</u> on <u>each</u> line.

How did this slide make you feel?

Afraid	___ ___ ___ ___ ___ ___ ___	Unafraid
Calm	___ ___ ___ ___ ___ ___ ___	Nervous
Disgusted	___ ___ ___ ___ ___ ___ ___	Elated
Secure	___ ___ ___ ___ ___ ___ ___	Insecure
Gloomy	___ ___ ___ ___ ___ ___ ___	Cheerful
Tense	___ ___ ___ ___ ___ ___ ___	Relaxed
Hostile	___ ___ ___ ___ ___ ___ ___	Friendly
Upset	___ ___ ___ ___ ___ ___ ___	Contented

How would you evaluate the slide in terms of the following characteristics?

Pleasant	___ ___ ___ ___ ___ ___ ___	Unpleasant
Unfavorable	___ ___ ___ ___ ___ ___ ___	Favorable
Interesting	___ ___ ___ ___ ___ ___ ___	Uninteresting
Negative	___ ___ ___ ___ ___ ___ ___	Positive

APPENDIX II: BIOGRAPHICAL QUESTIONNAIRE

QUESTIONNAIRE

PLEASE FILL THIS OUT BEFORE BEGINING THE EXPERIMENT

YOUR NAME ______________________________________

PHONE NUMBER ____________________________________

YOUR AGE ____

DO YOU WEAR CORRECTIVE LENSES ______________________(Yes/No)

DO YOU HAVE 20/20 VISION WHEN CORRECTED ______________(Yes/No)

HAVE YOU EVER BEEN HOSPITALIZED FOR HEART TROUBLE OR EYE PROBLEMS ________ (YES/NO)

IF YES, WHICH ________________________________

APPENDIX III: PROCEDURE FORM

SUBJECT NUMBER ____________

DATE ____________

READY ...

COMPUTER ...

CAMERA ...

RECORDER ...

EKG ...

SPR ...

BLOOD PRESSURE ...

PHOTOMETER ...

CHARTS ...

PAPER TAPE ...

SNELLEN CHART ...

FILL OUT QUESTIONNAIRE ...

EXPLAIN EQUIPMENT AND WHAT WE ARE MEASURING ...

HOOK UP TO APPARATUS ...

EKG ...

SPR ...

RESP ...

BLD PRESS ...

MENTION BUZZER--PART OF EXPT.--TRY NOT TO PULL AWAY

HOLD DOWN EYE BLINK AND SWALLOWING

BLINK EYES DURING BLANK SLIDES IF POSSIBLE

ADJUST LEVELS ...

ATTACH EARPHONES ...

ASK IF COMFORTABLE ...

DARKEN ROOM

2 MINUTE RUN TO FAMILIARIZE WITH WHAT WILL BE HAPPENING

START TAPE AND CHART ...

BEGIN PHOTOMETER RUN ...

PREPARE FOR STARTLE ...

. . . END OF RUN . . .

TURN CAMERA TO STANDBY ...

ASK SUBJECT TO FILL OUR QUESTIONNAIRE ON SLIDES ...

CLEAN ELECTRODES ...

RECYCLE TAPE RECORDER ...

CHAIR TO DOWN POSITION ...

DUMP DATA ON TAPE ...

RECYCLE COMPUTER ...

CHECK PAPER TAPE LEVEL ...

CHECK CHART PAPER LEVEL ...

REORDER SLIDES ...

COMMENTS

BIOGRAPHICAL SKETCH

Robert Roy Bell was born in Vincennes, Indiana, September 23, 1945. He attended grammar and high school in St. Francisville, Illinois. In 1961, Mr. Bell moved with his parents to Cocoa, Florida, where he completed high school in 1963. In the fall of 1963, he enrolled in Brevard Junior College at Cocoa, and received the A.A. degree in 1966.

In 1966, Mr. Bell enrolled in the University of Florida, where he received the Bachelor of Science in Business Administration degree, with honors, in 1969. He was a member of a team which represented the U.F. College of Business Administration at the Emory University Intercollegiate Business Games in 1969. During summer breaks, Mr. Bell worked for Trans World Airlines at the John F. Kennedy Space Center, Florida.

In March 1969, Mr. Bell was admitted to graduate work at the University of Florida, and received the Master of Arts degree in 1970. His studies were financed through a graduate assistantship in the Bureau of Economic and Business Research in the College of Business Administration. The title of his master's thesis was "An Investigation of Methodologies for the Measurement of Emotional Charging".

In 1970, Mr. Bell was awarded a National Defense Education Act Fellowship to continue his studies toward the Doctor of Philosophy degree. While completing his studies and writing his dissertation, Mr. Bell taught undergraduate courses in the Department of Management and Business Law.

Mr. Bell is a member of the Academy of Management and the American Institute for Decision Sciences. He has accepted an appointment as Assistant Professor of Management at the University of North Florida.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

William M. Fox, Chairman
Professor of Management and
Industrial Relations

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Walter A. Hill,
Associate Professor of
Management

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Marvin E. Shaw
Professor of Psychology

This dissertation was submitted to the Department of Management in the College of Business Administration and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1972

Dean, Graduate School

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